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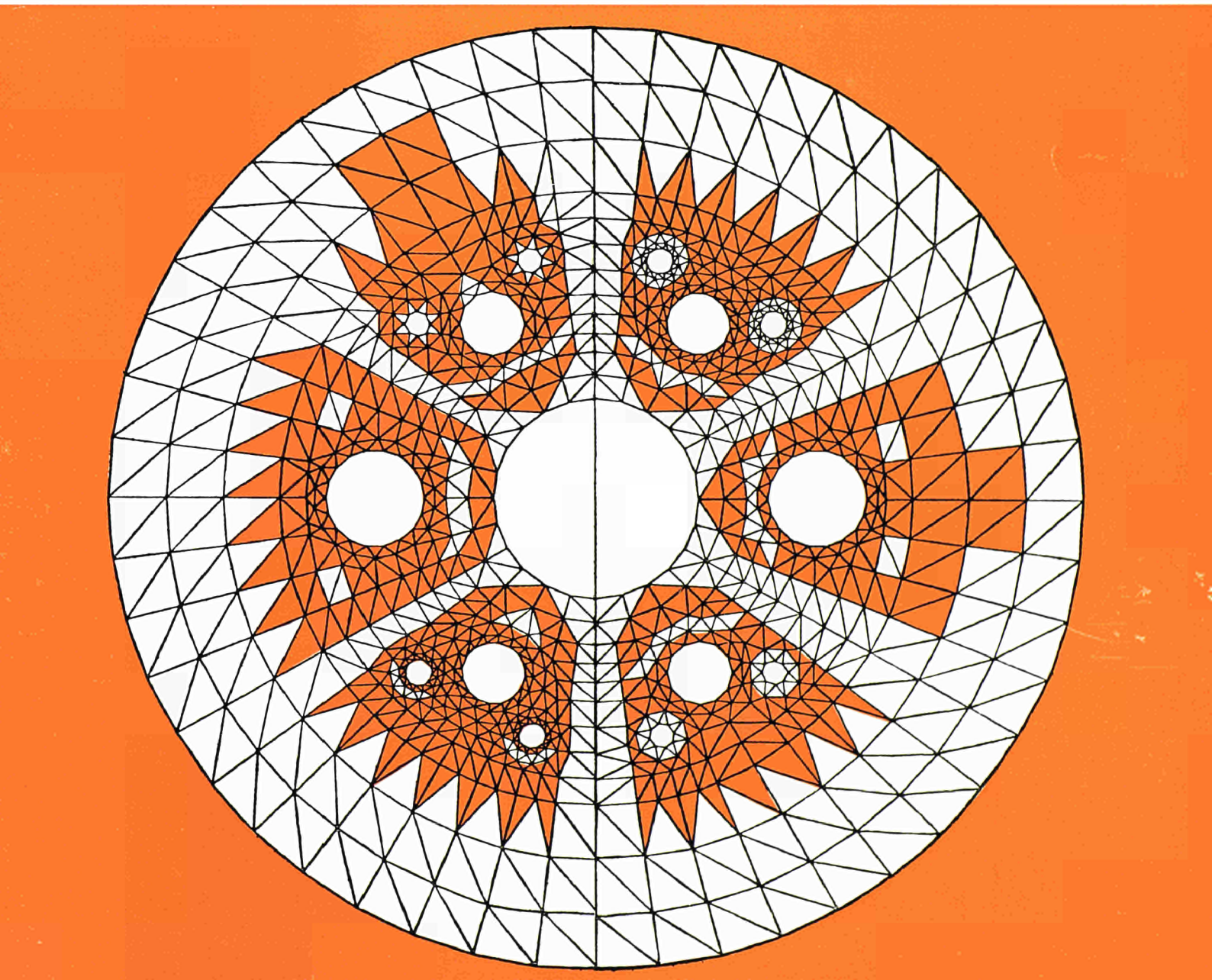

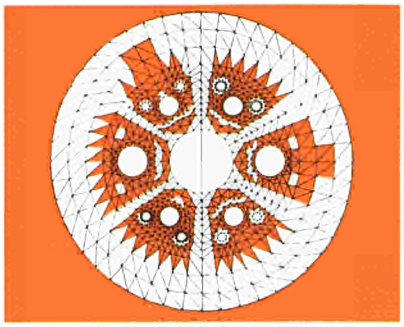

Fire-dance in prestressed concrete *(see p. 6)*

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1970-1

" Research News for Industry ", a new feature which will henceforth appear regularly in euro-spectra, will report recent original processes or devices stemming from the Community's research programmes. The idea is not to give a complete list but to draw attention to one or two inventions which look as if they would be particularly useful to industry.

The inventors are in most cases scientists at the Joint Research Centre whose work, for the present at all events, is chiefly nuclear. But readers who are only remotely or not at all concerned with the nuclear sector would be mistaken in assuming that the new feature holds no interest for them, for a great many techniques devised originally to overcome nuclear problems have since found applications in the conventional sector. Thus certain inventions developed under the Euratom research programmes, to look no further for an example, have been or are about to be adopted in the chemical, pharmaceutical, electronic, metallurgical, aeronautical and space industries.

Since innovation is now regarded as an essential factor for economic growth, it is important not merely to do research but to ensure that its fruits reach those who can put them to good use. That is our reason for launching " Research News for Industry ".

Concrete reactor pressure vessels - 1969 assessment

On 18, 19 and 20 November 1969 the Commission of the European Communities held a "Second information meeting on work relating to prestressed-concrete pressure vessels and their thermal insulation".
After the first meeting on this subject, which took place almost exactly two years previously, "Euratom Review" *assessed the state of the art at that time (see* "Euratom Review" *Vol. VII (1968) No. 1, pp. 18-23). The present article recapitulates the progress achieved since then and outlines the problems still to be solved.*

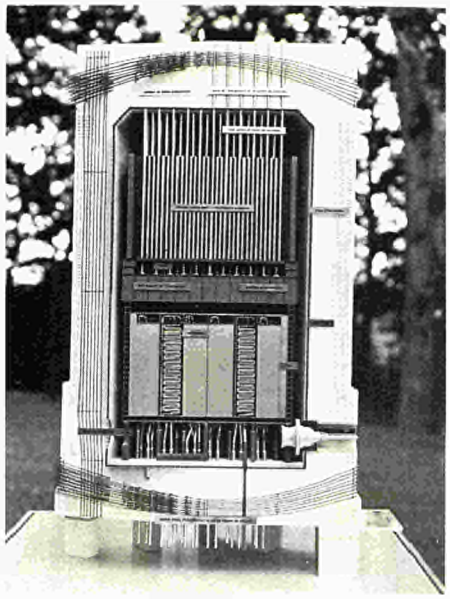

Figure 1 : *Reactor vessel of the* Saint-Laurent-des-Eaux I *nuclear power station.*

HARTWIG BENZLER and JAPIK TERPSTRA

PRESTRESSED-CONCRETE pressure vessels were originally developed for gas/graphite natural-uranium reactors. Today they have not only been adopted for other gas-cooled reactor families, the *AGR* and the *HTGR*, but are also being considered for use in water-cooled reactors, whether the coolant be in the form of light or heavy water, boiling water or pressurised water. It goes without saying that the various gas-cooled fast reactor projects that have been studied all make use of a prestressed-concrete pressure vessel.

As far as the gas/graphite family is concerned, ten reactors having a prestressed-concrete pressure vessel have been built, six of them in France, three in Britain and one in Spain.

Most of these reactors are already in service and the others are in an advanced stage of construction. In Britain four nuclear power plants, each equipped with twin *AGR*-type reactors having prestressed-concrete pressure vessels, are at present under construction. As regards the *HTGR* reactor family, this type of pressure vessel has now been used for the first time in the construction of the *Fort-Saint-Vrain* reactor in the United States. In Europe a decision is impending on the construction of two high-temperature gas reactors, each having a prestressed-concrete pressure vessel.

What are, broadly speaking, the advantages of prestressed-concrete reactor vessels as compared with steel vessels ?

First and foremost there is greater safety. Unlike steel pressure vessels, a prestressed-concrete vessel is not subject to brittle or explosive fracture. Furthermore, the occurrence of any leaks would be preceded by warning signs. There is consequently no need for a containment, as in the case of steel pressure vessels, and this represents a considerable saving.

Then there are the advantages that result from on-site fabrication of the vessel : no transport problems and no limit as to size. Finally, it seems that the construction times, which are already short in comparison with those of steel pressure vessels, could be further reduced by several months.

Under Euratom's second five-year programme a number of research contracts were concluded with Community organisations and firms with the aim of finding solutions to certain nagging problems that have arisen in this relatively new field. The Commission of the European Communities, anxious to ensure a wide dissemination of the results obtained, organised a first information meeting in November 1967.

In response to the interest expressed by the experts, the Commission decided to hold a second meeting, which duly took place in November 1969. Unlike the first, however, which had been restricted to representatives from the six Member States, this second conference was open to participants from other countries as well.

Practical experience with existing reactor vessels

Of particular interest among the reports on practical experience with existing reactor vessels was a comparison of the *Vandellos* plant in Spain and *Saint - Laurent - des - Eaux I* in France, which are to some extent parallel constructions though separated by an interval of three years. Both pressure vessels are designed for a maximum pressure of 30 bars, have an inside diameter of 19 m and an inside height of about 36 m. Although the two vessels are largely identical in design it was possible in the case of the second plant *(Vandellos)* to incorporate a number of novel solutions and detail improvements such as improved laying of the tendons and reduced cable friction in the cable ducts.

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The *Saint-Laurent I* plant was brought up to operating temperature and pressure for the first time in April 1968. Thereafter, numerous planned shut-downs and re-starts were carried out until March 1969, when the reactor was run up to full power for the first time. These tests showed that the structures behaved perfectly under the stresses due to pressure.

Apart from France it is mainly in the United Kingdom that extensive experience with prestressed-concrete reactor vessels is available. The review of practical experience to date with prestressed-concrete vessels was rounded off with a description of the principal construction problems in respect of the *Wylfa* power station, which is currently being commissioned by *British Nuclear Design and Construction*, and with a survey of the *Hartlepool* power plant, which is being built by the same consortium. Whereas for *Wylfa* it was decided to erect an internally spherical vessel with a diameter of 29.2 m, in the case of *Hartlepool* a cylindrical shape was chosen in which the steam generators are housed in separate recesses in the vessel wall *(pod-boiler design)*. The great advantage of this latter concept is that the steam generators can be installed and removed as complete units.

New pressure-vessel concepts

A special session of the information meeting was devoted to proposals for new pressure-vessel concepts and to the problems of model testing. As had emerged from the first conference two years previously, the technique of prestressed-concrete pressure vessels is still developing vigorously and is far from becoming static.

Particular interest was recently aroused by a pressure-vessel concept in which the circumferential prestressing reinforcement is arranged on and not in the cylindrical shell. Various possible solutions were put forward.

The firm of *Ph. Holzmann* of Frankfurt/Main has developed a wound multilayer circumferential prestressing system with equidistant tendons and intermediate anchors in the form of clamps which draw all the tendons together at several points on the vessel's circumference in a subsequently formed force-locked bond.

Four tensioning wires are wound on simultaneously by a machine. Fig. 2 shows a working model of this tensioning system for a pressure vessel of the type used in British gas-cooled reactors *(AGR)*.

The French *Commissariat à l'Energie Atomique (CEA)*, in collaboration with Messrs. *Coyne & Bellier* of Paris, has worked out proposals for a tensioning system in which the circumferential stresses are taken up by externally located hoops of high-strength steel strip. Each hoop consists of a band which is wound round the vessel several times. The prestress is generated by tensioning devices located between the concrete shell and the hoop. The efficacy of this system has been proved by tests (Fig. 3).

Siemens AG of Erlangen have developed a method of constructing prestressed-concrete reactor vessels which is based on a similar principle. In this case precast concrete segments are pressed outwards against closed steel tensioning hoops by means of radially acting hydraulic presses. The gaps left between the segments are subsequently filled with concrete, as a result of which the prestress is secured.

With all prestressed-concrete pressure vessels, and especially those intended for water-cooled reactors, it is essential that the reactor core be readily accessible from the outside, mainly for the purpose of refuelling.

There are three main ways of achieving this, namely by means of :

— a vessel whose upper portion is in the form of a removable cover and whose interior is therefore fully accessible ;

— a vessel which has at its top or its bottom a substantial number of access nozzles (i.e. the principle of the pressure vessels hitherto built for gas-cooled reactors) ;

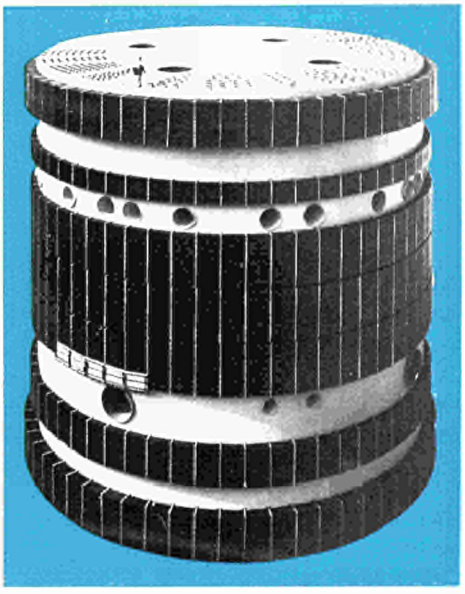
— a vessel having a fairly large central access opening that can be sealed by a suitable plug during operation of the reactor.

Prestressed-concrete vessels have so far been built solely for gas-cooled and not yet for water-cooled reactors, though numerous design studies for the latter have already been carried out in various countries. The main reason for this, apart from the difficulty of finding suitable means of heat insulation, is the problem involved in constructing an effective closure.

The *SOCIA* company of Paris has proposed several solutions to this problem, one of them being a prestressed-concrete vessel with a removable spherical cap, likewise of prestressed concrete, which is attached to the vessel's shell by means of a steel hoop structure (Fig. 4). The hoop structure is built up of plates and cross-ties and contains large cut-outs which enable the cap to be attached by means of removable bolts.

A project for a prestressed-concrete pressure vessel for a 600 MWe boiling-water reactor was put forward by *Société d'Etudes et d'Equipements d'Entreprise (SEEE)* of Paris and *Allgemeine Elektricitätsgesellschaft (AEG)* of Frankfurt/Main. This vessel consists of a cylinder with an inside diameter

Figure 2 : *Working model for wound circumferential prestressing reinforcement, as proposed by Messrs.* Ph. Holzmann, *Frankfurt/Main.*



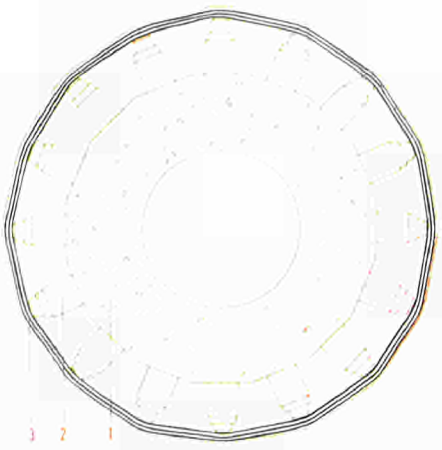


Figure 3 : *Principle of the circumferential pressing system with wound steel strip according to* CEA-Coyne & Bellier.
1) concrete shell ; 2) tensioning devices ; 3) steel strip hoops.

of 7.1 m and an inside height of 20 m, with flat closures at both ends. A penetration for the handling of fuel elements is provided in the centre of the upper closure, the remaining penetrations being grouped together in the bottom head (Fig. 5). The principal advantages of this solution as compared with a steel pressure vessel are : a reduction of about seven months in the construction time, increased safety and easier manufacture. It is also conceivable that further development work might lead to a system whereby quasi-continuous loading during reactor operation would be possible.

Model tests

Before embarking on the construction of any reactor vessel in prestressed concrete, and especially where new concepts are involved, it is still necessary to check the design, calculations and safety by carrying out model tests. *Fried. Krupp Universalbau*, Essen, reported on some interesting test results obtained with a 1 : 5 model of a multilayer vessel (see *Euratom Review* Vol. VII (1968) No. 1 pp. 18-23), while *Gulf General Atomic* of San Diego communicated the results of model tests for the first prestressed-concrete pressure vessel ever built in the United States (for the *Fort-Saint-Vrain* high-temperature reactor). Particularly noteworthy here is a pneumatic overpressure test which for safety reasons has hitherto usually been replaced by a hydraulic test.

Fig. 6 illustrates the crack behaviour of the multilayer model.

Calculation methods

The calculation of prestressed-concrete pressure vessels is today probably the most difficult task in the theory of constructional engineering. Only ten years ago it was still necessary to use a number of fairly rough idealisations in order to render these structures susceptible of calculation. Now, thanks to the availability of digital computers, the mathematical possibilities, both for the determination of material properties and as regards complex geometrical forms, are constantly being increased.

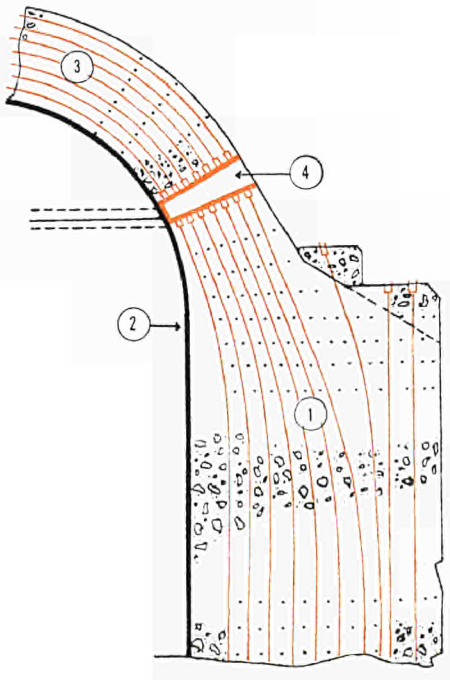
Five of the papers presented at the conference outlined the present state of development of the various numerical calculation methods, all of which can be reduced to only two basic mathematical formulations : the mechanical situation is stated in the form of differential equations or as a variation problem. By means of "finitisation", that is to say the fine geometrical subdivision of the structure as a whole, the separate treatment of large zones — which was the normal practice in classical mechanics — is replaced by a description of space elements of simple configuration. Fig. 7 gives an idea of this fine subdivision.

The main accent is on the development of automatic calculation programs characterised by maximum versatility and flexibility, which must operate economically. The principal requirement here is a thoroughly simple means of feeding in the boundary conditions and material laws. Thus the real problem consists in the development of methods which are entirely suited to the special characteristics of large computers (in particular their ability to perform organisational tasks and to carry out a multitude of similar operations in a very short time). The development to date indicates that in the future, in the investigation of complex structures, only the actual behaviour of the material and possibly some individual basic components will need to be studied experimentally, whereas the integral determination of the behaviour of the structure as a whole will be done by digital computers. Whole-model tests, which at present are still customary, will thus become more and more rare.

Material properties

In contrast to the methods for calculating prestressed-concrete pressure vessels — which methods will in future meet all accuracy requirements and are already enabling accuracies of within about ± 5 % to be attained — a far less satisfactory situation prevails as regards knowledge of the necessary material parameters, i.e. chiefly the dependence of the concrete strength and other properties on the stresses and temperatures that occur, on the moisture content in the material, on any irradiation it may have undergone and on its stress history. Where materials are concerned, therefore, a particularly wide-ranging fundamental research effort is still required.

Figure 4 : *Prestressed-concrete pressure vessel with removable cover, as proposed by* SOCIA.
1) vessel ; 2) metal liner ; 3) spherical cover ; 4) metal hoop structure.



Three papers dealt with the results of irradiation tests on experimental concrete structures. Whereas experiments in the Netherlands revealed that at up to fairly heavy radiation burdens (fluences of 3 to 8 $\times$ 10^{19} fast neutrons per cm^2) the direct radiation effect on the concrete properties is less significant than the indirect temperature effects, it is concluded from British experiments that in the fluence range 0.1 to 4 $\times$ 10^{19} fast neutrons per cm^2 the radiation effects are at least as great as the temperature effects. These partly conflicting results show how much scope there still is for research in this field.

Several contributions furnished new knowledge concerning the influence of temperature on the various mechanical, thermal and creep properties of concrete. Here again it seems that there are still certain discrepancies which ought to be clarified. A contribution from France dealt with the properties of a special heat-insulating concrete, while a British contribution discussed water migration in thick-walled concrete units. It was found that only very slow changes take place in the water content of such structures.

Finally, mention must be made of some particularly interesting experimental results obtained by a German firm concerning systematic measurements of the fracture behaviour of concrete subjected to multiaxial stresses. These results show that in the biaxial stress condition the fractures invariably occur in the stress-free direction, whereas under triaxial stressing they occur in the direction of least compressive stress or, of course, in the direction in which a tensile stress had been present. The destruction of the concrete is therefore caused solely by main normal stress fractures and not by shear fractures. This discovery opens up new prospects in the safety assessment of prestressed-concrete pressure vessels. Fig. 9 shows a machine developed by *Fried. Krupp Universalbau*, Essen, for measuring the strength of triaxially stressed material.

Need for thermal insulation

Against the many advantages and considerable development potential of prestressed-concrete pressure vessels must be set the drawback that they are sensitive to thermal stresses and are unable to withstand temperatures in excess of about 80° C. Consequently, an effective and reliable system of thermal insulation inside the vessel is essential. Such an insulation system consists of the following three components :

— an insulating layer which slows down the heat flux from the cooling medium to the vessel walls; the aim is to ensure that the greater part of the thermal gradient between the coolant and the ambient air is situated within this layer ;

— a metal plate which allows the calories leaking through the insulation to drain into a cooling circuit ; in most cases this function is fulfilled by the liner ;

— the above-mentioned cooling circuit.

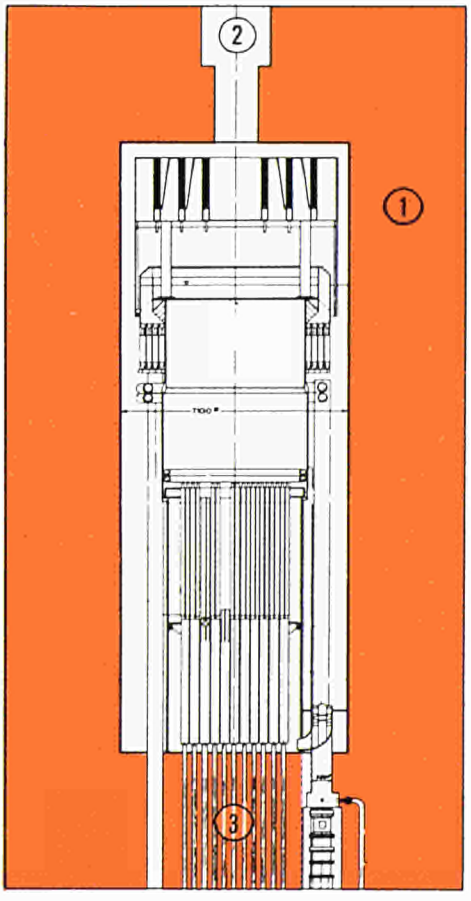
These components are normally arranged in such a way that the insulation is inside the liner, where it is immersed in the reactor coolant. The cooling circuit, on the other hand, is usually located outside the liner, where it is surrounded by the concrete. This arrangement, known as the "conventional concept", is the only one to have been used so far (Fig. 9).

There are, however, two variants which are of particular interest. They are known as the "hot-liner concept" and the "gas-wall concept".

Conventional concepts

In these concepts it is the insulation that presents the most serious problems, since it is immersed in the reactor coolant in a zone of extremely intense radiation. Numerous thermal and mechanical studies were conducted from the outset on a considerable number of insulating materials and structures. As the result, however, of some measure of elimination, the number of structures dealt with at the second conference was smaller than at the first.

Figure 5 : *Prestressed-concrete pressure vessel for a boiling-water reactor, as proposed by* SEEE *and* AEG.
1) prestressed-concrete vessel ; 2) opening for refuelling machine ; 3) penetrations for control rods.



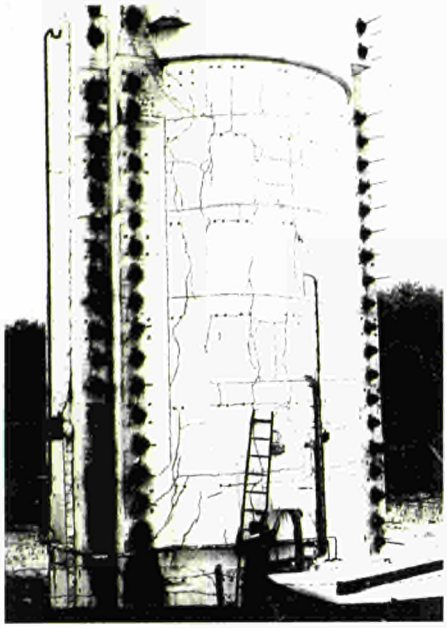


Figure 6 : *Crack pattern after load cycles of up to 86 atm peak load on the* Fried. Krupp Universalbau *model (design pressure 43 atm).*

Refractory concrete, which had been chosen as a solution for the first large reactor vessels in France and was then dropped in favour of the system based on corrugated foils and metal cloths *(Metalisol)* designed by *Compagnie des Ateliers et Forges de la Loire (CAFL),* has undergone a revival of interest since the development of improved versions by the French *Atomic Energy Commission (CEA).* These new concretes possess a number of highly satisfactory characteristics, chief among which is the ease with which they can be applied during an early stage in the construction of the vessel. It seems, moreover, that the quality of these materials is improved by contact with CO_2 at ambient temperature.

Metallic insulations, both of the fibrous *(CAFL)* (Fig. 10) and of the cellular *(Darlington Chemicals Ltd., Sud-Aviation)* type, have already been successfully used in industry for several years. These insulations, which are constructed in a high-grade and clean material, have the advantage of being usable at temperatures up to about 850° C, i.e. for all reactors in which a (primary or secondary) steam cycle is employed. The use of *Metalisol* insulation in the *Bugey* reactor and in a boiling heavy-water reactor were described respectively by participants from *CAFL* and *SOCIA.* The application of a cellular insulation system based on corrugated metal foils was dealt with in a contribution from *Sud-Aviation.*

A general problem with metallic insulation systems stems from the high thermal conductivity of the base material, which can give rise to undesirable interactions between the individual components of the insulation. A proposal for a fundamental study of these interactions was presented by the Ispra Establishment of the *Joint Research Centre.*

Nuclear insulation systems on a mineral-fibre basis, which only a few years ago were still regarded with disfavour, have recently met with outstanding industrial success. They have been adopted for four nuclear reactors (two power stations) of the *AGR* type and one high-temperature gas reactor. The material chosen was kaolin wool but other mineral fibres, e.g. silica wool, can also be used. It is essential that the basic materials of the fibres be particularly pure and that they do not contain any neutron absorbents, notably boron.

Some fundamental studies on convection movements in a fibrous medium (which movements must be eliminated if an insulation system is to function properly) were reported on by *Bertin et Cie* and *Compagnie de Saint-Gobain* (Fig. 11) as well as by *The Nuclear Power Group.* These theoretical and experimental studies, which were carried out under both simulated and real conditions, are without doubt largely responsible for the recent success of fibrous insulations. Among these studies special mention must be made of the model tests with a pressure gradient along a gas-permeable hot surface such as occurs in a reactor vessel. Unfortunately, no report on the use of fibrous insulations was presented at the conference.

Gas-wall concept

This concept, which is a variant of the "water-walls" and was developed by *SOCIA* and *Deutsche Babcock und Wilcox,* is characterised by the fact that both the insulating layer, composed of mineral fibres and stainless steel foils, and the cooling circuit are situated inside the liner. This arrangement, which makes it possible for many of the components to be prefabricated, has the special feature that the primary coolant of the reactor serves also as the fluid for the cooling circuit. This feature makes for a high degree of safety and furthermore, the cooling circuit does not need to be particularly leak-tight. Naturally, the specific problems in respect of the insulating layer

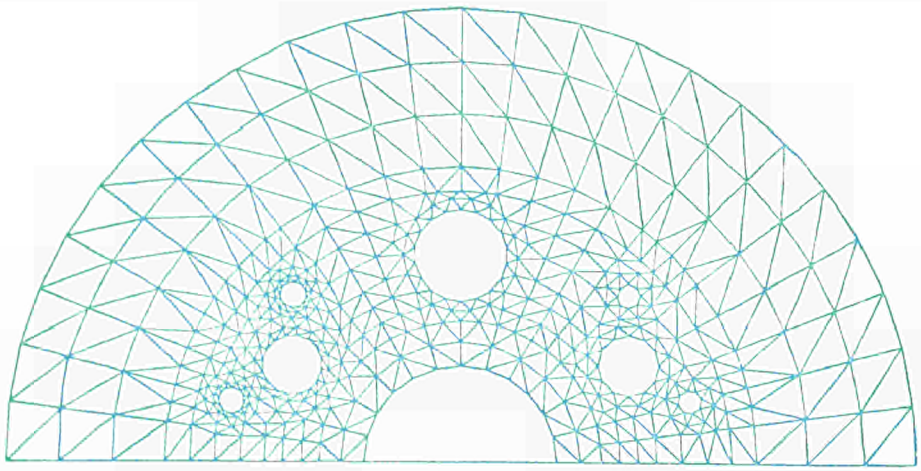
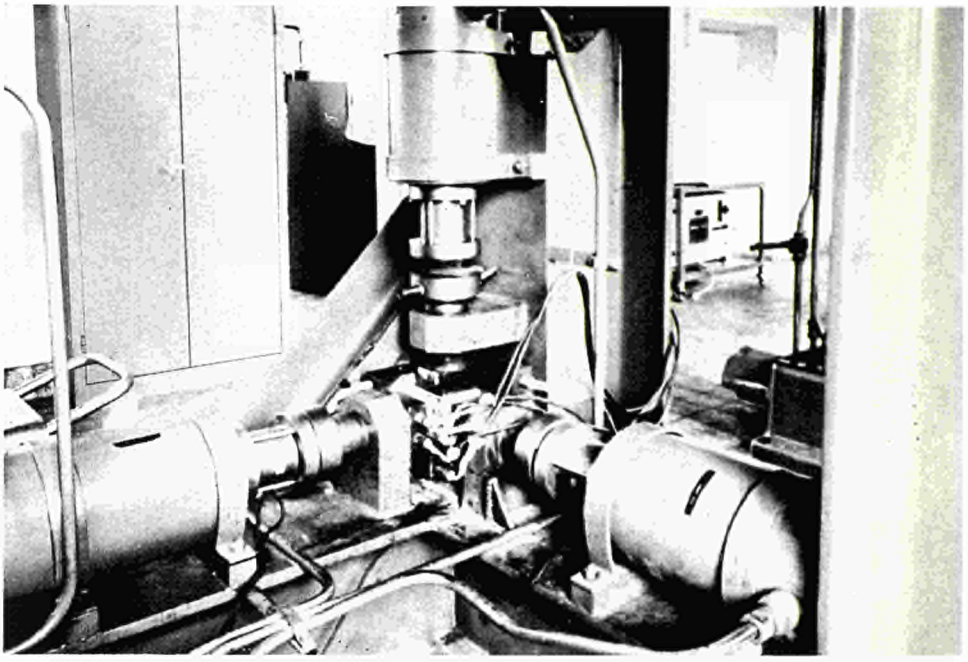


Figure 7 : *Fine subdivision of a pressure-vessel cover for numerical calculation, according to* General Dynamics, General Atomic Division *(USAEC Report 1966, GA-7150).*

Figure 8 : *Machine for measuring the strength of concrete under tri-axial stress conditions. Developed by* Fried. Krupp Universalbau, *Essen.*



are the same as in the case of the conventional concept. The design has now reached the stage of industrial maturity.

Hot-liner concept

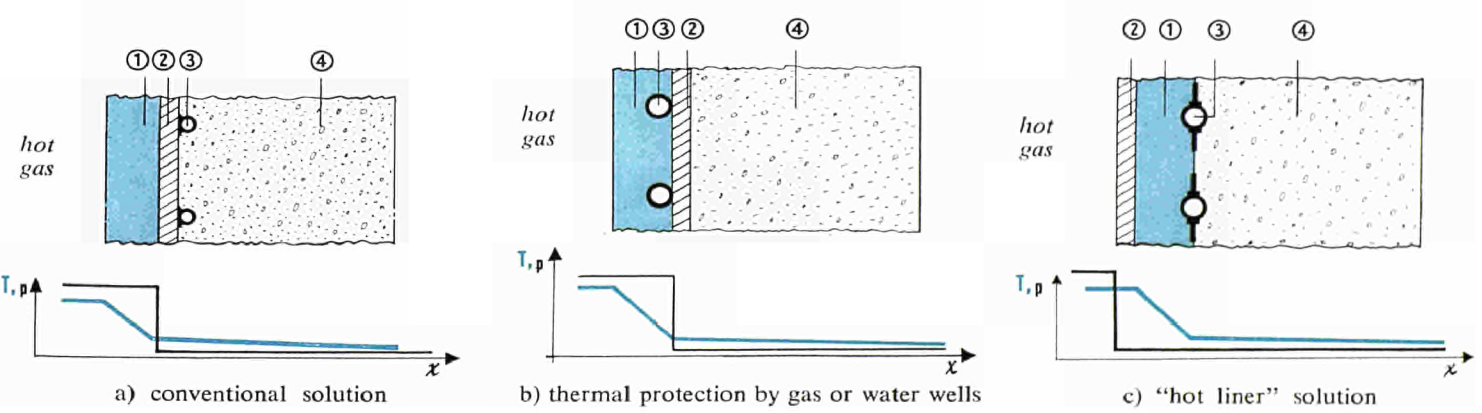
In this concept, developed by *SEEE*, the arrangement of the thermal shield components, from the inside to the outside of the pressure vessel, is as follows : liner, insulating layer (of refractory concrete), cooling circuit. In this case it is the liner, which is subjected to extremely severe thermal and mechanical stress conditions, that gives rise to the trickiest problems. This very interesting concept has been studied in greater detail for application to a boiling-water reactor vessel. In fact, in the particular case of water reactors it is free from all of the problems posed by the conventional and the water-shield concepts (these problems are discussed below).

Application to the various reactor types

On the whole it can be said that satisfactory industrial-scale solutions exist for *gas reactors* with CO_2 cooling; a different situation exists, however, where helium-cooled reactors are concerned. When helium at high temperature is present the heat losses through the insulating layer on the inside of the vessel are due mainly to conduction and infra-red radiation. In the case of CO_2-cooled reactors, on the other hand, it is natural convection that predominates unless special precautions are taken. The insulation systems developed for the latter reactors must therefore be adapted to work satisfactorily in the presence of helium. Considerable progress in this direction has already been achieved. Reports on this subject were presented by the *Dragon Project* and by *Bertin & Cie.*

A particular problem arises, however, in certain zones of reactors employing a direct cycle, in which the helium is required to leave the core at a temperature of 850° C or, prefe-

Figure 9 : *The three basic thermal protection systems for prestressed concrete reactor vessels (in the graphs, the temperature curves are shown in colour and the pressure curves in black). — 1) insulation ; 2) liner ; 3) cooling ; 4) concrete.*



a) conventional solution

b) thermal protection by gas or water wells

c) "hot liner" solution

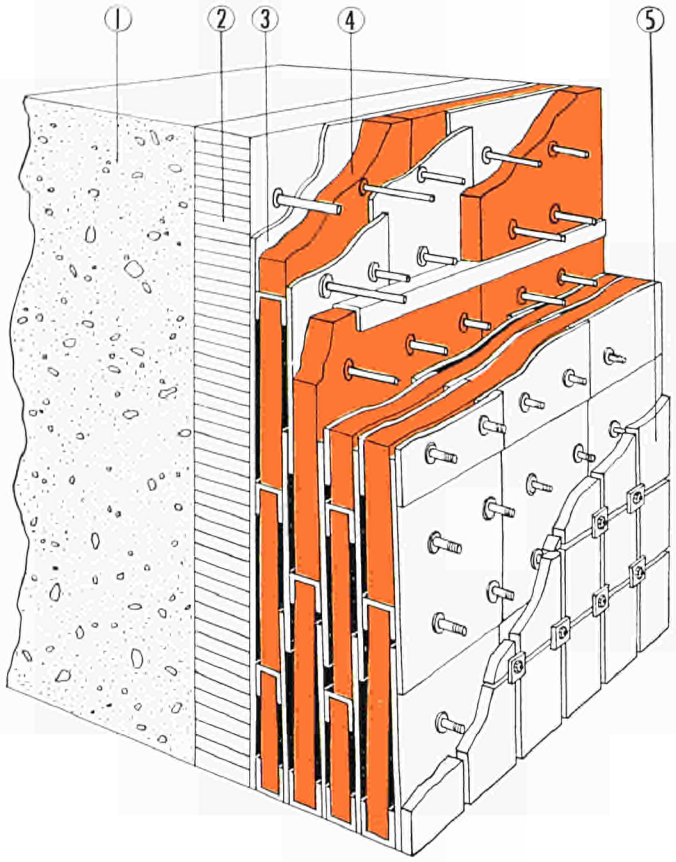


Figure 10 : Métalisol *insulation system designed by* Compagnie des Ateliers et Forges de la Loire *(the assembly is illustrated in the non-tightened condition).*

1) concrete ; 2) liner ; 3) stainless-steel sheet ; 4) mattress composed of metal cloths ; 5) casing.

rably, much higher still. At these temperatures the steel casings on which all the thermal shielding concepts depend for integrity can no longer be used and it is difficult to see what material could replace steel in these casings. Silicon nitride has been suggested as an alternative, but obviously this low-ductility material would necessitate careful adaptation of the casing structure and of the method of attaching the casing to the leaktight liner.

Another field of research in which numerous problems have yet to be solved is the mechanical behaviour of insulation systems under stresses of aerodynamic origin. These problems arise primarily during normal reactor operation, at points where high primary coolant velocities prevail, but also in the event of an accident when the reactor is suddenly depressurised or when the circulators stop. *Bertin & Cie* have studied the vibrations that might have occurred in the insulation of the *Bugey-1* reactor and the means proposed for their prevention. The Ispra research establishment reported on a test rig which enables a helium decompression rate of 100 bar/sec to be obtained (Fig. 12).

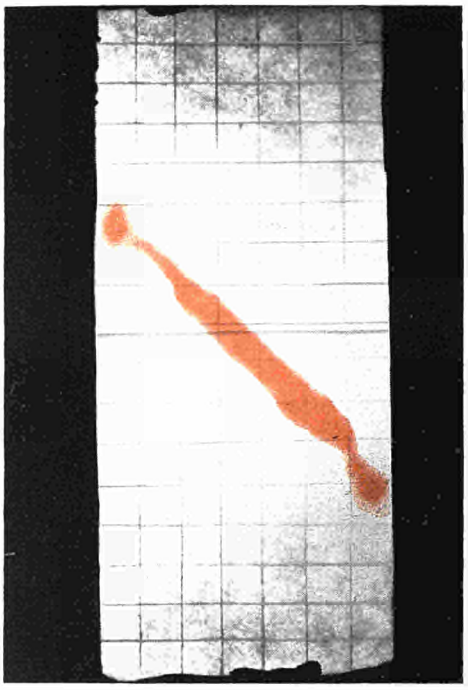
It also seems that the very high sound intensity inside a gas-cooled reactor gives rise to problems with certain insulation systems. Unfortunately, no communication on this subject was presented at the conference.

As far as *water reactors* are concerned there is at present no satisfactory solution that can be adopted on an industrial scale. Despite all the precautions that can be taken against the development of convection currents, an insulation system immersed in water will inevitably have a high thermal conductivity owing to the high conductivity of the water itself.

Solutions which aim at obviating this drawback by providing a gas zone at the insulation call for a pressure-equalisation system between this gas and the water and thus enormously complicate the arrangement of the internal structures in the reactor vessel (Fig. 13). A design developed by *AB Atomenergi*, in which the thermal shielding zone of the vessel wall is transferred to a removable dome, merits close attention since it allows of inspection and, if necessary, repairs during refuelling (Fig. 14).

In addition, the condensation of steam in the cold parts of the insulation and the corrosion of its constituent materials by the water are extremely grave problems which have scarcely been tackled so far.

Having said this, let us now revert to the hot-liner concept, which completely eliminates these problems. If the difficulties concerning the mechanical behaviour of the liner can be suitably solved — which should be easier in the case of water reactors in view of their relatively low temperature level — this concept would be truly ideal.



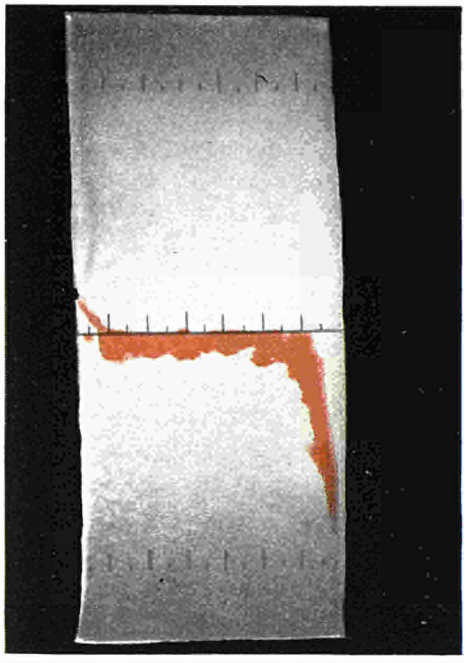


Figure 11 : *Convection movements rendered visible in a leaktight parallelipipedal cell containing mineral wool immersed in a fluid.*
The photographs represent a closed cell filled with glass wool through which monochromatic light is passed. The cell simulates a single element in a fibrous insulation system. In order to render it transparent, the reactor coolant was replaced by chlorobenzene, which has the same refractive index as glass.
The left-hand vertical surface is heated, whereas the right-hand one is cooled. The heat transfer between these surfaces takes place essentially by natural convection in the chlorobenzene. A rising boundary layer removes heat from the hot surface, while a descending boundary layer, which develops on the cold surface, gives up the same quantity of heat to the latter.
In the second experiment (illustrated on the right) the temperature difference is greater than in the first.
The dark area represents the progress of a thread of coloured liquid injected with a syringe along the horizontal line seen in the centre of the picture. The two photographs reveal a clockwise turning movement. In the first, the velocity curve is virtually linear, the boundary layers on the hot and cold surfaces of the cell are thick and are in contact throughout the greater part of the cell ; this is known as convection with "contiguous boundary layers". In the second picture, on the other hand, the flow velocities are high in the vicinity of the walls and practically zero at the centre of the cell ; this phenomenon is known as convection with "discrete boundary layers".
A thermally ideal insulation system should be designed in such a way that no convection can occur. In practice, however, it is possible to make do with a system composed of elements which behave as in the first picture. The development of "discrete boundary layer" convection movements (second photograph), which involve a much greater heat transfer, is inadmissible.

Figure 12 : *Test rig at the Ispra Establishment of the* Joint Research Centre *for the rapid depressurisation of thermal insulation models. With the aid of this apparatus it is possible to study the behaviour of insulation systems in the event of a serious accident, e.g. disintegration of a blower or plug.*

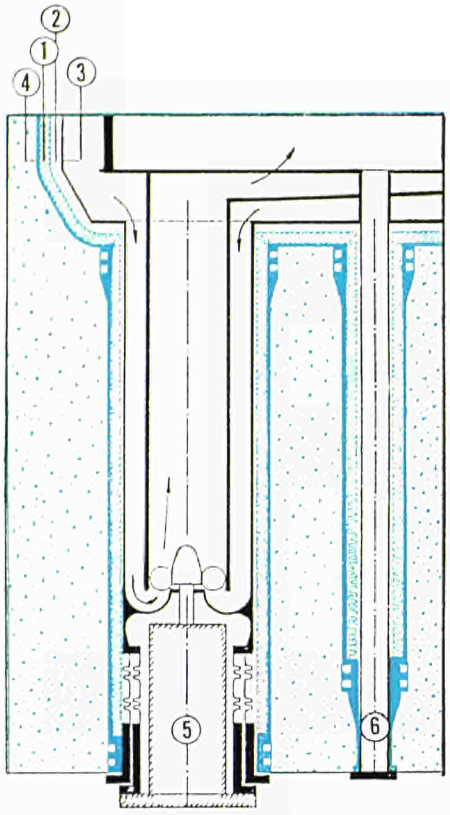


Figure 13 : *Two penetrations in the bottom head of a prestressed-concrete pressure vessel for a heavy-water reactor designed by* SOCIA.

A layer of gas separates the inner vessel containing the heavy water from the thermal insulation.

1) insulation ; 2) gas layer ; 3) inner vessel ; 4) liner and its cooling system ; 5) circulating pump ; 6) control rod.

Research and development programmes

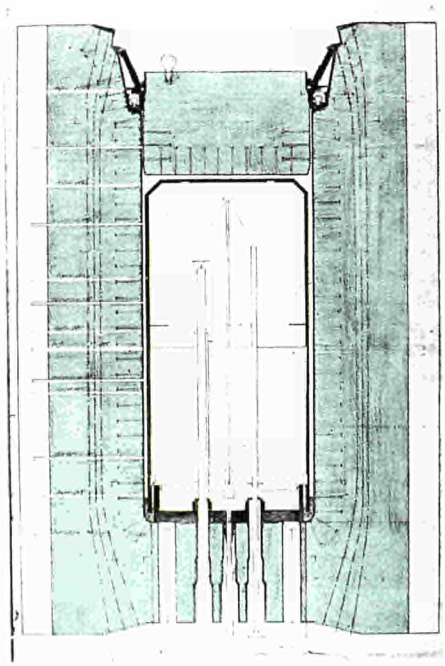
The present technical and intellectual frontiers in the technology of prestressed-concrete pressure vessels and their thermal insulation systems can only be pushed back at the cost of an additional research and development effort. The major industrialised countries are aware of this fact and started some time ago to draw up appropriate basic national programmes. Details of the American and German multiannual programmes were dealt with in contributions and discussions during a session of the information meeting which was devoted specifically to these questions. In this connection it should also be noted that at the end of 1969 four of the most experienced construction companies in France set up a special research association for nuclear reactor vessels *(Société d'Etudes des Caissons Nucléaires)* to carry out all the relevant research and development projects.

Conclusions

Today there is no longer any doubt as to the attractiveness of prestressed-concrete pressure vessels, both from the safety point of view and as regards economy. This is true above all of gas-cooled reactors. Moreover, the substantial effort that many firms have made as regards their application to water-cooled reactors is indicative of the advantages they see in them.

A comparison of this second information meeting with the preceding one reveals the considerable progress that has been achieved in the last couple of years. Large resources are, however, necessary if further progress is to be made, and a coordination of efforts, especially in the field of fundamental studies, is desirable. EUSPA 9-1

Literature : (1) *Proceedings of the Information meeting on work relating to prestressed concrete vessels and their insulation. Brussels, 7-8.11.1967. EUR 4280 d/f/i/n/e.* (2) In preparation : *Proceedings of the Second conference on prestressed concrete reactor pressure vessels and their thermal insulation. Brussels, 18-20.11. 1969.*



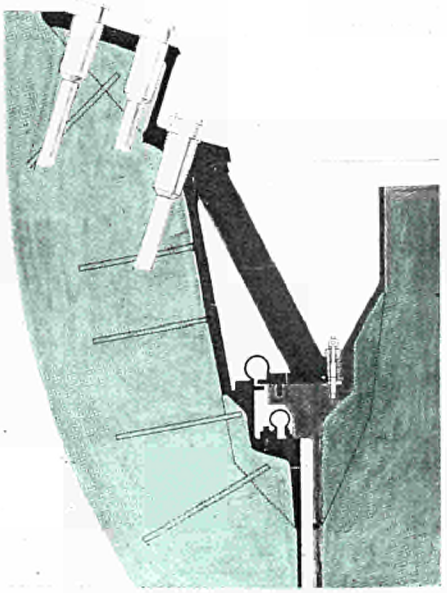


Figure 14 : *Swedish design for a prestressed-concrete pressure vessel for a boiling heavy-water reactor* (AB Atomenergi). *The water and steam are contained in a removable metal dome located inside the vessel. The insulation layer for protection of the top and the cylindrical part of the vessel is applied to this dome and is situated in a gas zone between the dome and the liner. The cooling circuit is in the usual place, embedded in the concrete, outside the liner.*

At the side, a detailed view of the closing mechanism for the plug/cover assembly.

A computerised information system faces its customers

The Euratom Nuclear Documentation System has gradually improved over the years, largely thanks to customer "feed-back".

The customer today still needs an expert documentalist to act as an "interpreter" between himself and the system. Further improvements will however soon enable him to converse directly with the computer.

CARLO VERNIMB

IN THE FIELD of scientific and technical information the use of computers is still far from commonplace. However, a number of computer-aided systems now have several years of operation behind them. Have the high hopes which attended the launching of these projects been fulfilled ? An attempt will be made here, if not to answer this question, at least to provide some data on the working of one such automated service, namely the *Euratom Nuclear Documentation System (ENDS)*, and to sketch in the lines along which future improvements are being sought.

ENDS is based on coordinate indexing, i.e. the allocation, to each of the documents which are introduced into the system, of a list of keywords indicating the nature of the document's contents. (The indexing operation is usually carried out on the basis of an abstract rather than the original document.) Every incoming query is similarly expressed in terms of keywords. Thus the retrieval operation, i.e. the process whereby the documents containing information relevant to the query are pinpointed, consists in having the computer compare the keywords of the query with the keywords of each of the documents stored in the system. The customer is eventually supplied with a set of cards on which the abstracts of each of the retrieved documents are copied. (The *ENDS* system has already been described in some detail in this periodical and elsewhere — see bibliography.)

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Feedback as payment

Over 3,000 queries have already been processed by *ENDS*. As those who have sent queries and received answers to them will know, we ask all customers to submit a detailed appreciation of the material supplied. As long as we do not ask for payment in the usual sense, this "feedback" is the only remuneration which we require.

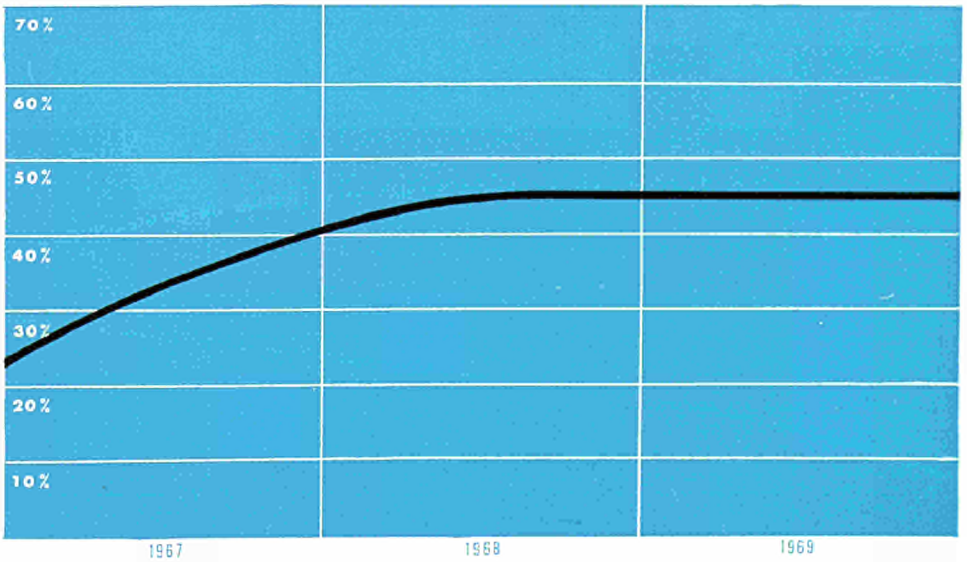


Figure 1 : *Relevance ratio of* ENDS *literature searches (period 1967-1969).*

Thus the customer is expected to tell us which of the supplied references he knew already, which are pertinent and were unknown to him, which are not quite pertinent but nevertheless useful and which are not pertinent at all ; finally, the customer is asked to indicate any pertinent references which we failed to send him.

By this procedure we obtain a fairly good picture of the customer's degree of satisfaction. Furthermore, we carry out extensive checks in order to establish why we did not retrieve the missing documents.

Relevance ratio

Figure 1, which was drawn on the basis of the figures sent in by customers, gives the relevance ratio of the *ENDS* service, i.e. the percentage of documents indicated to the customers which we recognised as relevant. It can be seen that the relevance ratio has risen through the years, a tendency which is mainly due to the accumulation of experience in the "translation" of queries into keywords, leading to improved query formulation.

Evaluation of customer satisfaction

Figure 2 gives a graphical impression of the time history of "customer satisfaction". The solid white line represents the percentage of documents for which no further action was necessary. The dotted white line corresponds to that part for which the customer, although agreeing in principle with the results supplied, asked for fuller information. The part remaining between the solid black line, which gives the total of these two percentages, and 100 % represents the cases in which the customers stated that their requirements had not been met, owing to misinterpretation of their query or insufficient accuracy in their own initial formulation of the query. It can be seen from the black line that customer satisfaction has now risen to about 90 %.

Figure 3 is a summary, in the form of a diagram, of retrieval and feedback evaluation : of a hundred abstracts screened for an average literature search, 56 were discarded as non-relevant (or "noise") and 44 sent to the user. Of these 44 references, 10 were regarded by the user as non-relevant and 34 as relevant (8 being known to him already).

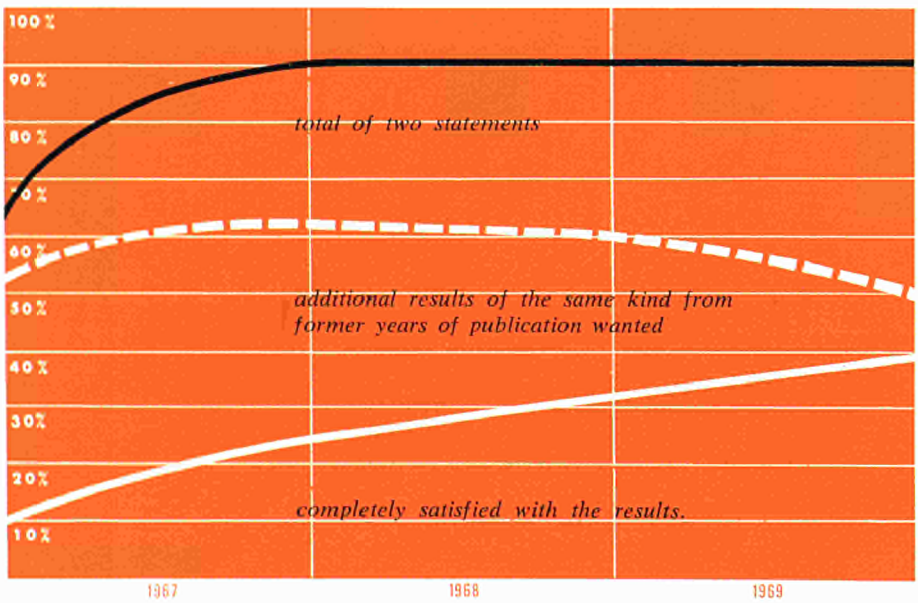
It should be stated that the average figures given relate to several hundred queries treated neither with undue superficiality nor with excessive concern for exhaustiveness, i.e. real-life queries.

From comparisons with very thorough manual searches we know that there are, on average, 12 pertinent references which the system fails to retrieve (one of which the user knows already). Of these 12 "misses", 8 are due to poor abstracting, 2.5 to poor indexing and 1.5 to poor retrieval.

Speeding up the service

Customers are, of course, interested not only in the quality of the answers but also in getting them quickly. Figure 5 shows the different stages into which query processing is split up and the time needed for each stage. It can be seen that considerable time is spent on query formulation by the subject specialist, on punching and machine processing of the query, on abstract card drawing, and especially on manual

Figure 2 : ENDS *customer satisfaction (period 1967-1969).*



screening of the abstracts, i.e. separating relevant and non-relevant references.

Each individual operation can be carried out only after completion of the preceding step ; it can therefore be calculated that the total time taken to process a query, even if the indispensable computer run is effected at night, will be about 24 hours. In actual practice, however, many queries are handled in parallel, which results in delays or waiting times. According to our experience the number of queries under treatment at any given moment has to be multiplied by 0.3 to get the total processing time in days. Thus, if 40 queries have to be treated, their processing time is 12 days.

These statements are based on the present strength of the *ENDS* staff and the stage of development reached by the system today. It is clear that if we can automate some of the operations, the way is open towards a reduction in the processing time, not to mention a reduction in cost.

It is in a sense absurd, for instance, that the comparatively sophisticated retrieval operation should be automated, whereas the mundane task of drawing abstract cards is still left to the human hand. Several firms are, however, working actively on this problem and we hope to have available, in a not too distant future, equipment capable of selecting abstracts out of a large collection (in our case about one million to date) and producing copies of them, all according to instructions given directly by the computer.

As can be seen from figure 5, the screening process is that which takes up most time. Unlike the drawing of abstract cards, moreover, it requires highly qualified staff. As we shall see later, this problem is also on the way to being solved.

When is a manual search preferable ?

In figure 6 the effort (in time or money) needed to obtain information is given for manual and machine searches.

In a manual search some information can already be gained at a small effort ; in a machine search a fairly large effort is required before the first item of information is obtained. Therefore, if a relatively small amount of information is needed, it does not pay to pass the query to a computerised documentation centre. In this case a library should be consulted, and it should be the task of librarians to screen out such preliminary queries.

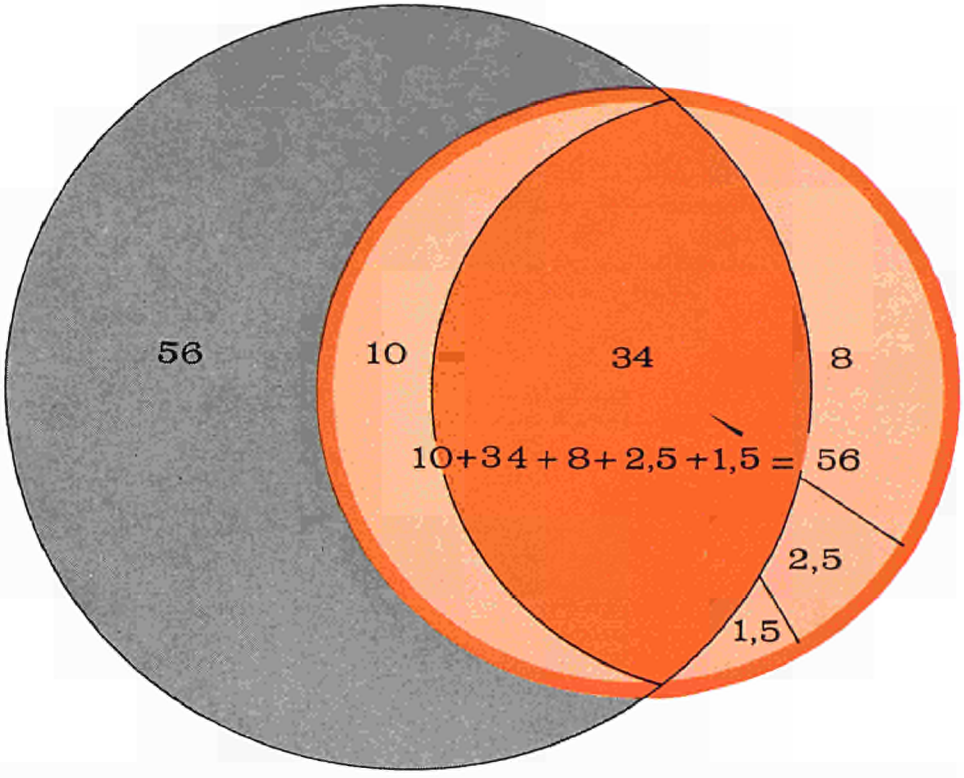


Figure 3 : *Aiming at an average target in the* ENDS *documentation system.*

An average ENDS *target (coloured circle) consists of 56 documents. In other words, 56 published documents holding information relevant to the average query are stored in the system.*

An average computer retrieval operation yields 100 documents (large circle), 57 of which are discarded as "noise", i.e. as irrelevant, by an ENDS *documentalist (left-hand portion of large circle).*

Thus the attention of the customer is drawn only to the 44 remaining documents, of which he discards 10 (left-hand portion of target) and recognises only 34 as true "hits" (centre portion of target). Twelve documents (right-hand portion of target) are missed completely, 8 owing to incomplete abstracting, 2.5 to incorrect indexing and 1.5 to inadequate retrieval. If this page is taken to represent the total number of documents stored in the system (nearly one million), then the average target is only the size of this dot.

Are complete bibliographies always necessary ?

There is another relation expressed by the machine search curve : to retrieve 90 % of the available information the effort is about three times as high as for the retrieval of 60 % of the available information. According to the experience gained from our feedback campaign the customer will generally be satisfied with 60 %.

Nevertheless most of the customers ask for "a complete bibliography". As long as we are not in a position to charge him different prices for a complete bibliography and for a general survey of the subject, we try to make it more difficult for the customer to ask for a complete bibliography by asking him to tell us how many documents on the subject he is aware of already, and how many he expects to receive. These questions are included in our new forms for requests.

The key to good retrieval : precision in query formulation

In traditional documentation systems a scientist has to search through alphabetical indexes and library card files grouped according to subject, author, etc., and to scan suitable abstract jour-

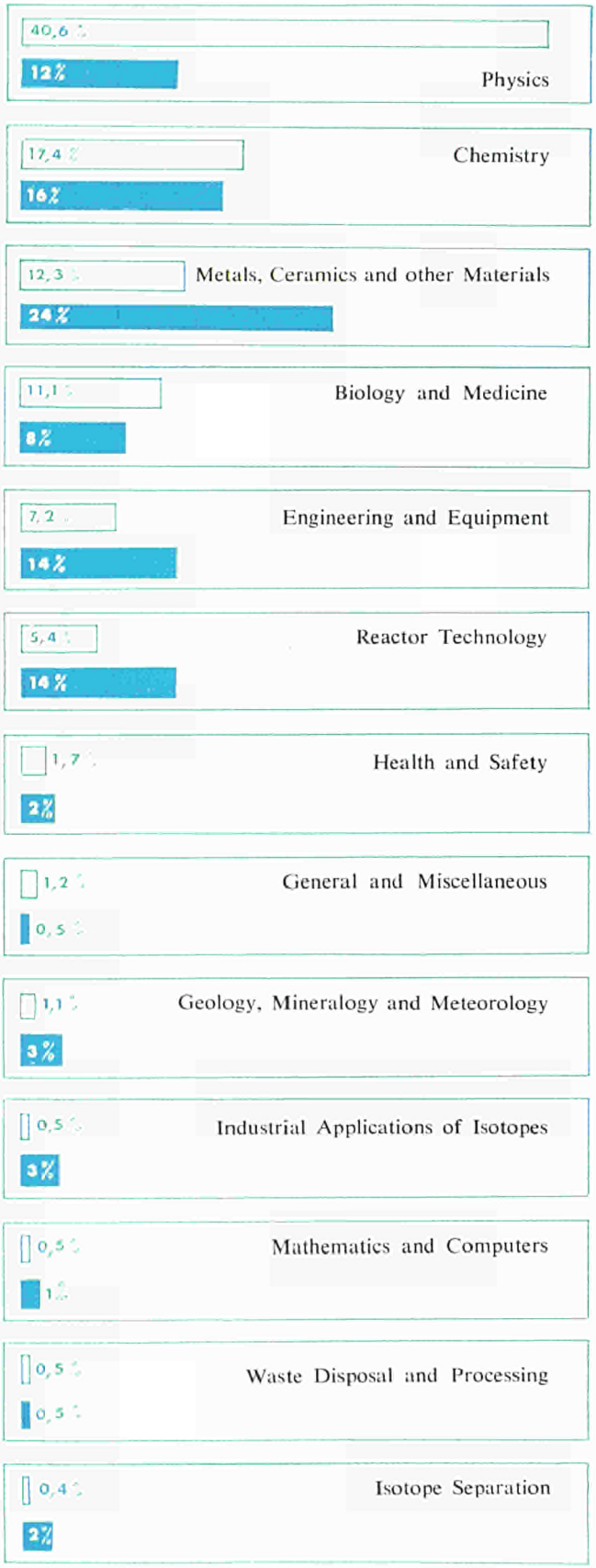


Figure 4 : *Which are the favourite subjects? This figure gives a breakdown of documents fed into the computer memory (white areas) and of queries (coloured areas) according to subject field (basis of statistics : 1,400 queries). There is an important difference in the "input" (more than 40 %) compared with the « output » (12 %) in physics. On the other hand, it should be noted that the "output" in metals and ceramics, engineering and equipment and reactor technology is two to three times as high as the "input".*

The reason for the relatively small number of queries in physics seems to be that physicists believe they will not obtain references they do not know already from our documentation system. (In actual fact, many who tried it out had to confess they were wrong in this respect.)

In general it can be stated that there is a considerable interest in document dealing with properties of materials. Another statement which can be made is that the "output» in industrial applications of isotopes is six times as high as the "input".

nals. To begin his search, he needs a heading by which to enter the subject indexes. If he does not immediately find an answer to his problem, he tries again under some other entry. After he has checked a few of the references found, other entries will, as a rule, occur to him, and he will start searching anew. Such a manual literature search uses single-term entries and involves the use of what might be termed "instant feedback". The scientist may start with only a vague idea of his problem ; instant feedback will add precision to his query.

In most of the modern computerised documentation systems based on coordinate indexing and retrieval, a documentalist acts as an intermediary between the scientist and the system. This fact makes it neccessary for the documentalist to have a clear idea of the scientist's problem so that he can add precision to his query.

In our experience with *ENDS* it is just this accurate statement of the query which is the most difficult problem. In our request form for literature searches which the applicant is asked to use, we therefore give him the following hint : "Define the subject with enough precision to ensure that a documentalist specialised in your field but not necessarily acquainted with your particular subject can thoroughly understand the question and also recognise what would not be of interest to you".

But this advice has proved insufficient to change the habits of the scientists using our system. Most of them still put their queries in the traditional single-term form. We have therefore resorted to more stringent measures which find their expression in the somewhat aggressive guidelines printed on the back of the request form, where we read, for instance : "Do not ask for *radioactive strontium compounds* when you can ask more precisely : *Which radioactive strontium compounds will in reactor operation be generated within the fuel elements from the strontium produced in uranium fission by chemical reactions with other components of the fuel elements (e.g. carbon, oxygen in UC or UO_2), and so on...*

Figure 5 : *The different stages of query processing.*

The query is of interest because decontamination measures in the event of damage to a fuel element will be dependent on the nature of the strontium compounds escaping. Your query should therefore resemble a short abstract rather than a title".

These rather brusque directions have already had some effect. It has become much less frequent for us to have to ask the user to word his query clearly.

Another experience is that a user finds it easier to reveal details and define his needs more exactly on the telephone than in a letter.

Selective dissemination of information

Sofar we have dealt with "retrospective" literature searches. Something should however be said about selective dissemination of information *(SDI)*, i.e. periodical information on recent publications dealing with a certain subject. *SDI* is intended to replace the traditional browsing through primary and secondary journals.

For preparing an *SDI "profile"*, we have adopted the following procedure. At first, each *SDI* search is handled like a retrospective search and the user is requested to supply feedback.

When feedback has been received, the query is reformulated in order to reduce machine output as far as possible to such references as the user found to be relevant, ensuring, of course, that no relevant item is lost.

Feedback is indispensable because the user could have in the meantime changed, or simply made up his mind. But there is another reason for reformulating the query, i.e. the experience the documentalist will have gained in checking the relevance of the documents retrieved in the retrospective search.

Here is an example : we received the query "Control of operation of power reactors by computers". We first formulated it as follows (+ means "or" ; * means "and") :

(CONTROL + CONTROL SYSTEMS + MONITORING)
* (OPERATION + STARTUP + SHUTDOWN)

* (POWER PLANTS + REACTORS)
* (COMPUTERS + DIGITAL SYSTEMS + ANALOG SYSTEMS)

The primary retrieval terms CONTROL, OPERATION, POWER PLANTS and COMPUTERS were supplemented by near-synonym terms which could have been used instead in indexing.

With a system volume of 900,000 documents this query resulted in 180 documents retrieved, 40 of which proved to be relevant ; consequently, the relevance ratio was calculated as 22 %.

When checking the relevance of the documents retrieved, the documentalist detected, first, that the terms DIGITAL SYSTEMS and ANALOG SYSTEMS contributed no relevant items and, second, that many references were retrieved in which the computer was used for calculations (indicated by the keyword NUMERICALS) or for simulating the behaviour of reactors. Furthermore, he realised that the indexers might have used only one term of the first two lines of the query formulation to index a relevant document. "Control of power reactors by computers" could be a title for a relevant document just as well as "Operation of reactors by computers". As a consequence, the first two lines were combined, resulting in the new query formulation (*-means "and not" :

(CONTROL + CONTROL SYSTEMS + MONITORING + OPERATION + STARTUP + SHUTDOWN)
* (POWER PLANTS + REACTORS)
* (COMPUTERS)
*- (NUMERICALS + SIMULATORS)

This query yielded 660 documents, 480 of which proved to be relevant — a relevanve ratio of 73 %. Thus, by reformulating the query, the number of pertinent items retrieved increased by a factor of 12.

By making use of the documentalist's experience in screening the results of retrospective searches, together with customer's feedback, it was possible to obtain an average relevance ratio of about 75 % for *SDI* searches. There is perhaps no other large documentation system in operation in which such a high relevance ratio is being achieved.

A look to the future : doing away with documentalists

The fact that the user's effort will decrease as he changes over from the traditional to the computerised system will at first please him, but his enthusiasm will be somewhat dampened by the need to adjust to a new technique. Even the higher yield of useful documents obtained by the computerised system will not deceive him as to the fact that he must rely upon the system documentalist as an intermediary, and that he cannot start a search possessing only a vague idea of what he wants. The single-term-entry method with instant feedback would in this case offer some advantage. And who can say whether the latter method is not better suited to the human way of thinking ?

The problem is thus how to do away with the system documentalist (figure 7). This could be done by

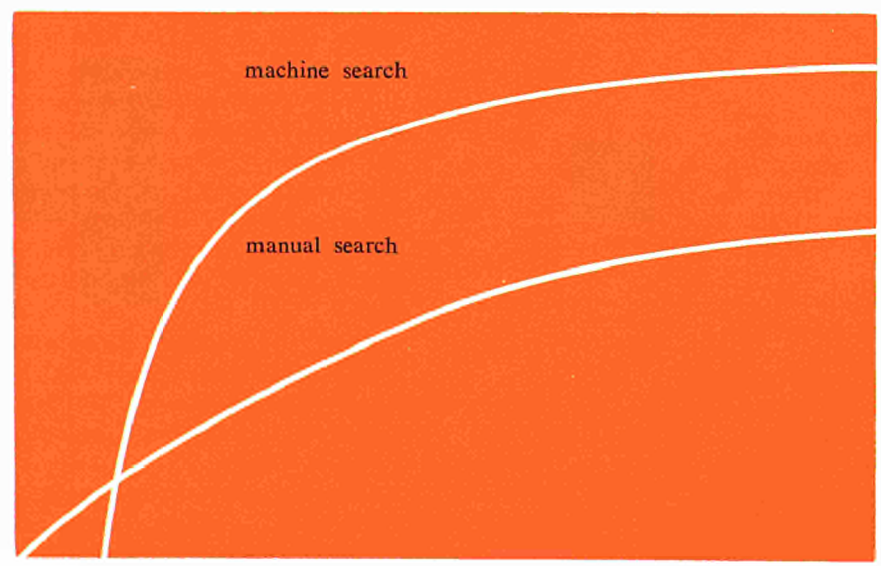


Figure 6 : *Effort (in time or money) needed to obtain information through manual and machine searches.*

Figure 7 : *Documentation systems and the user's effort.*

User's effort

Searching via single term entries (headings) in alphabetical indexes ; instant feedback permitting more precise search.

Traditional documentation system

Subject indexes
Library card files
Abstract journals

User's effort

Formulating a precise query, commenting on results and rephrasing the query if necessary (delayed feedback).
Effort is less than when working with a traditional system.

System documentalist

Interpretation of query and its formulation by logical coordination of search terms ; checking the results and reformulation of the query if necessary. Considerable effort.

Computerised documentation system

with coordinate indexing and retrieval

shifting the borderline between the user's and the documentalist's efforts to the right, or by shifting the borderline between the documentalist and the system to the left, or even by shifting both borderlines towards each other.

We had some disappointing experiences in getting the user interested in query formulation. For such a simple query as "Isotope enrichment of uranium 235 by ultracentrifuges", one user looked up the Euratom Thesaurus and proposed the formulation :
ISOTOPES * ENRICHMENT * URANIUM 235 * ULTRACENTRIFUGES

But an indexer assigning URANIUM 235 should never add the term ISOTOPES. Moreover, according to a specific indexing rule, the keyword ISOTOPE SEPARATION would have to be used. The correct formulation should have been :
ISOTOPE SEPARATION * (URANIUM 235 + URANIUM ISOTOPES) * ULTRACENTRIFUGES.

The user's formulation would have yielded virtually no answer — and this is a simple example only. It can hardly be expected that a user will, just to process a few queries a year, learn all the indexing and retrieval rules the documentalist has to know.

To try and make the system documentalist superfluous, we must, in our opinion, shift the borderline between the system and the documentalist considerably to the left, and the borderline between the user and the documentalist only a little to the right. Shifting the former borderline to the left means, first of all, direct access to the computer. Direct access is being used in several experimental documentation systems. However, to the best of our knowledge, and as far as performance is concerned, it will not be possible to replace the documentalist by direct access alone.

We can count on the ability of the user to judge between pertinent and irrelevant documents. What we need is

a system which will present to the user — by way of direct access — documents or abstracts of documents on which he can base his judgment concerning relevance, which is then directly fed back into the system.

Lut us sketch roughly the interaction between user and system without the documentalist as intermediary :

1) The user feeds his query into the computer in natural language, via a console.

2) The query is indexed automatically, i.e. keywords are derived from it.

3) The system presents these keywords, as well as semantically related keywords, via a television screen, to the user, who chooses the most appropriate and coordinates them by the logical operation "and" and "or".

4) The system then indicates the number of answers that would be retrieved by the proposed formulation, and the user is given the possibility of reducing the number of answers by adding a keyword (with « and »), representing an additional condition, or of increasing the number of answers by leaving out less significant keywords.

5) Bibliographical data or abstracts of the documents retrieved are shown up on the screen.

6) The user checks these documents for relevance until he has obtained, say, four clearly pertinent and four characteristically irrelevant documents.

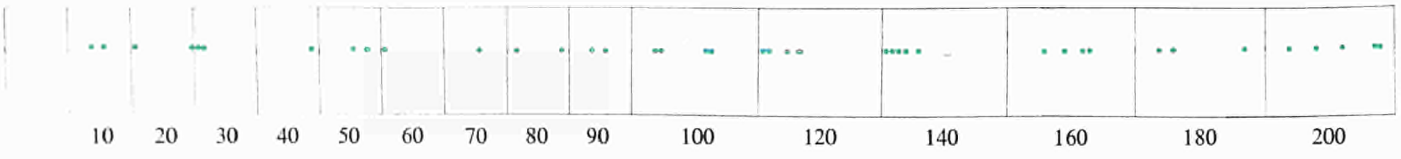
7) The reference numbers of the clear "hits" and of the characteristic "noise" are fed back into the system.

8) Thanks to such a relevance feedback procedure the remaining retrieved answers to the query are ranked automatically in the order of their pertinence probability. A document will have high pertinence probability when the combination of keywords allocated to it is very similar to that of documents already found to be pertinent.

9) The user checks the ranked documents for relevance, on the screen if the number is limited, or on a computer printout supplied to him if the number is higher.

The last few stages of this procedure may seem somewhat futuristic, but we think we have already brought them nearer to reality, as a result of our efforts to remedy what is perhaps the weakest point in the *ENDS* system, namely the manual screening of the references retrieved. As already mentioned, this operation not only takes a long time but also requires highly qualified staff.

The solution we have found to this problem applies to queries which give a large number of answers, and these are precisely those which cause most trouble from the screening point of view. It consists in taking a small sample of the retrieved documents (10 - 20) and checking their relevance from their abstracts. The document numbers are then fed into the computer, together with the indication "relevant" or "irrelevant". So far, this is the documentalist's job. The rest is left to the computer, which, after examining



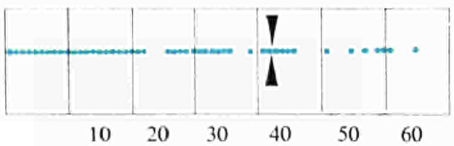


Figure 8 : *Example of result obtained when applying the computerised "relevance feedback" procedure.*

The query dealt with "uranium isotope separation" and yielded 220 answers, 41 of which (represented by the white dots in the top line) were found after manual checking to be relevant. In the computer output, the references are in this case arranged simply according to their serial number in the collection.

If the "relevance feedback" procedure is applied, the "hits" tend to appear first (bottom line). Manual checking can therefore be dispensed with : it is enough to "cut" the output at a certain point.

the keywords assigned to the documents retrieved, gives each document a higher or lower ranking according to whether the group of keywords assigned to it bears a greater resemblance to those assigned to the documents declared to be relevant or to those declared to be irrelevant.

Figure 8 presents an example of the results which can be achieved by adopting this method. The query dealt with "uranium isotope separation" and yielded 220 answers, which were carefully checked for relevance in order to set the stage for a test of the efficiency of the "relevance feedback" procedure ; 41 were found to be relevant to the query (relevance ratio : 18.6 %). The points on the top line in the figure represents these "hits". (The references are arranged simply according to their serial number in the collection.) When it came to applying the "relevance feedback" procedure, the first 20 references only were checked and three were found to be relevant. (This corresponds to a relevance ratio of 15 % for this small sample.) These three "hits", and three clear "misses" selected out of the 17 non-relevant references found in the sample, were used as a basis for the procedure. The result is shown in the second line : the "hits" were shifted to the left, i.e. they tended to be found among the first references. It is reasonable to send the first n references only to the user (where n is the product of the sample relevance ratio, in this case 15 %, and the total number of answers to the query, in this case 220). That means that in this particular case the "cut" should be made at $n = 33$. As can be seen from the second line, 31 of the first 33 references are "hits", which gives a relevance ratio of 94 %.

Such a result can be sent to the user without hesitation. If the user is interested in a more complete search, he may ask for the references which attained a lower relevance ranking.

This "relevance feedback" procedure has thus contributed substantially to the automation of retrieval and to a reduction of the documentalist's role as an intermediary between the user and the system.

Table I : *Origin of queries processed in 1969 by the* ENDS *system (expressed as a percentage of the total).*

Community	
Institutions of the European Communities	24.3
Germany	21.0
Belgium	18.8
France	16.7
Netherlands	5.0
Italy	3.9
Luxembourg	0.7
Non-member states in Europe	
Austria	2.7
United-Kingdom	2.3
Switzerland	0.3
C.S.S.R.	0.2
Denmark	0.1
Sweden	0.1
Non-member states outside Europe	
Israel	1.5
Canada	1.2
Turkey	1.1
Argentine	0.1
Total	100 %

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Isotope generators - a review of the present state of development

Isotope generators — "nuclear cows" — have many potential uses, especially in medicine.

HORST BERNHARD, KARL HEINRICH LIESER

THE USE of nuclear reactors and accelerators makes a large number of radionuclides available. Radionuclides with a half-life of several hours or days are used in medicine for diagnostic purposes. This trend has shown a clearly perceptible expansion in recent years.

Of particular significance from a diagnostic standpoint is the chemical composition of marked compounds. Thus, as a result of modification of its chemical form, a specific nuclide can be used for diagnostics in various areas, e. g. thyroid, bloodstream, tumours, liver, kidney, brain or lungs.

As radiation damage in the tissue is something which must be prevented as far as ever possible, it is desirable to use radionuclides which are pure gamma-emitters. The optimum energy range of the gamma-emitters employed is 0.1 - 0.4 MeV. This is sufficiently hard to reveal deeper-lying regions of the body, even if intermediate skeletal structures cause greater absorption (e. g. in cerebral examinations). In addition, radiation of this energy can still be efficiently collimated, which is essential for pinpointing the damage to be investigated.

Considerable interest attaches to the use of short-lived radionuclides for securing a very substantial reduction in the radiation dose to the patient. Table I affords a comparison of two strontium isotopes of different half-lives with respect to the dose to the subject. It is seen from the table that the short-lived Sr-87m (pure gamma-emitter, half-life 2.8 hours) produces only a few per cent of the radiation burden which would be expected from the application of Sr-85 (beta- and gamma-emitter, half life 65 days). Appreciably higher Sr-87m activities could therefore be used for examination purposes, which, even for a shorter measuring time, ensures a far higher degree of diagnostic accuracy.

In the field of technology, short-lived radionuclides are used for flow measurements and leak detection. The entire range of such radionuclides is, however, comparatively small.

On account of the radionuclides' short half-life, they have to be generated or obtained, as the case may be, at the place where they are to be used, transportation involving a considerable loss in activity. A solution whereby short-lived radionuclides can be made available to research establishments which are not equipped with reactors or accelerators consists in the use of isotope generators or "nuclear cows". This article gives a survey of the present state of research in this field and

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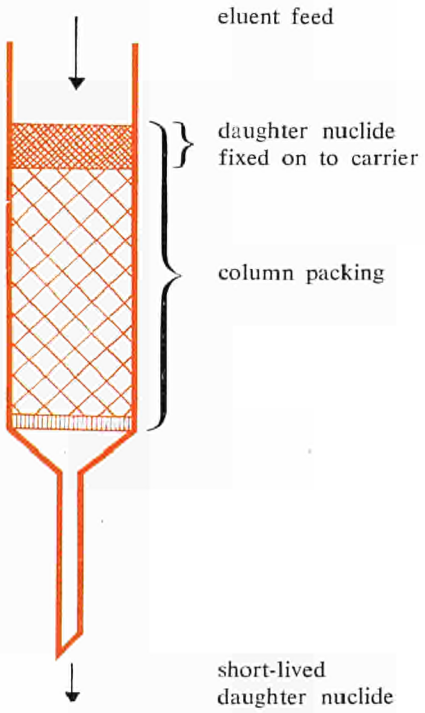
Fig. 1: *Isotope generator separating column.*



discusses the possibilities for the development of new generators.

Characteristics of isotope generators

An isotope generator (see Fig. 1) contains a relatively long-lived parent nuclide which is fixed on to a carrier and whose chemical form allows the rapid, simple and repeated separation of the daughter nuclide with the desired short half-life, produced as a result of radioactive decay. Since the daughter is continuously formed by the decay of the parent, the separation can be repeated at regular intervals. This arrangement makes it possible for a short-lived radionuclide to be despatched and stored virtually on the basis of the longer half-life of the parent. Furthermore, the separated nuclide is free from ponderable amounts of the element's stable isotopes, a very important point in many investigations.

Another advantage is the large amount of activity that is made available by repeated "milking" of the cow. For example, during three half-lives of the parent nuclide, 1 mCi Ge-68 will yield a total of 862 mCi Ga-68 if the cow is milked a ten-hourly intervals ; if the milking is done at intervals of five hours it is even possible to obtain a yield of 1.6 Ci Ga-68.

So far eight types of cow are commercially available and a number of others have been described in the literature on the subject. They supply the respective daughter nuclides with a good yield and at very high purity. The users consequently have at their disposal several short-lived radionuclides with widely differing nuclear and chemical properties, and this affords a large measure of adaptation to the problem under study.

Requirements to be met by isotope generators

An isotope generator for medical, industrial or laboratory use must meet the following requirements :

a) Handling must be easy as regards both actual operation and radiological protection; the simplest method consists in fixing the parent nuclide in a column and eluting the daughter.

b) It must be possible to effect separation quickly.

c) The daughter must be of high radiochemical purity; this requirement is particularly important in medical and technological applications, as any contamination by the parent nuclide would have undesirable effects. The purity of the daughter is given in the form of a "decontamination factor", which expresses the ratio between the daughter activity and the parent activity in the separated solution. Decontamination factors of 10^4 - 10^8 are desirable, depending on the half-life of the parent.

d) The activity obtained should be available directly, or at least without complicated manipulations, for further use.

e) The parent activity must remain in a form which allows the greatest possible number of milking operations.

Available parent-daughter systems

Table II summarises the parent-daughter systems which are of interest for isotope generators. For the sake of convenience the systems are arranged according to the position occupied by the daughter and parent nuclides in the periodic table. Commercially available isotope generators are specially indicated in the table. Additional information is provided by the decay data on the individual nuclides. The literature references relate both to fully developed generators and to published proposals.

Table I : *Comparison of Sr-87m and Sr-85 with respect to the radiation dose in diagnostic examinations. The values shown are the upper and lower limits.*

Nature of radiation dose	Average radiation dose (mR) for :	
	100 µ Ci Sr-87m	100 µ Ci Sr-85
Bone	9,9 — 2,2	1590 — 3700
Whole body	0,7 — 2,2	680 — 1100

From Table II it emerges that the range of short-lived radionuclides that can be produced with the aid of isotope generators is very extensive, so that suitable nuclides are available for solving a variety of medical and technological problems in a simple manner.

Further development

Nevertheless, many problems in the field of isotope generator technology have still to be solved. For instance, when an isotope generator has to be used for any great length of time, the behaviour of the parent nuclide in the separating column is of particular importance. The parent nuclide must be sufficiently firmly fixed so that it is not released after a few milkings and contaminates the daughter. In addition, the isotope generator must have a good storage stability, so that, even when a fairly long time has elapsed since it was last used, the radiochemical purity of the nuclide it contains is undiminished.

Particular importance is attached in the medical field to the question of contamination of the daughter by the parent substance, especially where the same patient has to be subjected to repeated diagnostic tests. In such a case, an accumulation of the parent nuclide in the patient could result in a high, uncontrolled dose. In the case of frequent administration, therefore, attention must be paid to a possible accumulation of the long-lived parent nuclide in the organs under study. Such considerations are especially important when the parent nuclide has a long half-life.

For chemists engaged in the development of new generators, the fixing of the parent nuclide on a carrier constitutes a very interesting problem. The range of possibilities extends from adsorption to the chemical fixation of complex compounds by chemical bonding. However, with long-lived nuclides, which in theory would enable a generator to be used for years on end, the possibilities are limited by the migration of the parent nuclide on the column. When a milking system is charged with substantial amounts of activity it is also necessary to take into account the radiation burden of the carrier substance, which sets a limit to the life of the generator. In view of the relatively high sensitivity of organic substances to ionising radiations it seems desirable to use inorganic carriers.

Tendencies in the further development of milking systems are towards the use of long-lived parents. Their appreciable operating life makes the application of such generators profitable even when milking is performed at irregular intervals. The best eluent for simple conversion of the eluted nuclide into any desired chemical form is distilled water. This aim can be achieved only by using very specific carrier substances.

For direct application of a nuclide in medicine it is important to keep the eluate sterile and pyrogen-free. Recently an increasing number of sterile models have come onto the market which contain a storage tank with an eluent solution, the separating column and the elution vessel in a compact arrangement. The technical design of such generators ensures easy and safe handling as well as safety with respect to radiation protection.

Such models are of considerable interest, particularly for medical purposes, in "black-box chemistry" form; i. e. it will be the task of researchers in this field to develop long-life isotope generators which also offer a high degree of safety when used by non-chemists.

(*) Full names of suppliers :

Amersham : The Radiochemical Centre, Amersham, England.

NEN : New England Nuclear Corporation, Boston, Mass., USA.

BNL : Brookhaven National Laboratory, Upton, N.Y., USA.

CEA - CEN - SORIN : Commissariat à l'Energie Atomique, 91-Gif-sur-Yvette, France, Centre d'Etude de l'Energie Nucléaire, Mol-Donk., Belgium, Sorin, Saluggia (Vercelli), Italy.

Duphar : Philips - Duphar, Amsterdam, Netherlands.

Buchler : Buchler & Co., Braunschweig, West Germany.

Hoechst : Farbwerke Hoechst, Frankfurt/M., West Germany.

ble II : *Summary of commercially available and proposed isotope generators.*

Position in periodic table		Properties of parent nuclide			Properties of daughter nuclide			Literature references	Suppliers*
arent clide in roup	Daughter nuclide in group	Nuclide	Half-life	Type of radiation and energy (MeV)	Nuclide	Half-life	Type of radiation and energy (MeV)		
	0	Rb-83	83d	K capture γ0.52 ; 0.53 ; 0.55	Kr-83m	1.9h	Isomeric transition γ0.009	—	—
I	0	Ra-226	1600a	α4.78 ; 4.60 γ0.19	Rn-222	3.82d	α5.49 γ ...	—	—
		Ra-224	3.64d	α5.68 ; 5.45 γ0.24	Rn-220	55.6 sec	α6.29 γ ...	—	Buchler
II	I	Ac-227	21.5a	β⁻0.04 γ ...	Fr-223	21.8m	β⁻1.2 γ0.05 ; 0.08	2, 3	—
	II	Cs-137	30.0a	β⁻0.5 ; 1.2 No γ	Ba-137m	2.55m	Isomeric transition γ0.66	4, 5, 6	—
II	II	Y-87	80h	β⁺0.7 γ0.48	Sr-87m	2.8h	Isomeric transition γ0.39	7	Amersham, NEN, Duphar
		Ac-227	21.8a	β⁻0.04 γ ...	Ra-223	11.43d	α5.68 ; 5.45 γ0.24	—	—
I	III	Mg-28	21.3h	β⁻0.5 γ0.03 ; 1.35 ; 0.40 ; 0.95	Al-28	2.3m	β⁻2.9 γ1.78	8, 22	—
		Sr-90	28.1a	β⁻0.5 No γ	Y-90	64.1h	β⁻2.3 ; ... No γ	9, 22	BNL
		Cd-115	2.3d	β⁻1.11 ; ... γ0.52 ; 0.49	In-115m	4.5h	β⁻0.8 γ0.34	10	—
		Ba-140	12.8d	β⁻0.5 ; 1.0 γ0.54 ; 0.16 ; 0.30	La-140	40.2h	β⁻1.4 ; 2.2 1.60 ; 0.49 ; 0.33 ; ...	11, 12	—
II	III	Ce-144	284d	β⁻0.3 γ0.13 ; 0.08	Pr-144	17.3m	β⁻3.0 γ0.70 ; 2.19 ; 1.49	—	—
V	II	Th-228	1.9a	α5.34 ; 5.42 γ0.08 ; 0.22	Ra-224	3.64d	α5.68 ; 5.45 γ0.24	24	—
V	III	Ti-44	47.3a	K capture γ0.078 ; 0.068	Sc-44	4.0h	β⁺1.5 γ1.16 ; 2.54	17	—
V	III	Ge-68	275d	K capture No γ	Ga-68	68.3m	β⁺1.9 γ1.08 ; 0.80	16, 22	Amersham, NEN
		Sn-113	115d	K capture γ0.26	In-113m	1.66h	Isomeric transition γ0.39	14, 15	Amersham, NEN, Duphar
VI	IV	U-238	4.5.10⁹a	α4.20 ; 4.15 γ ...	Th-234	24.1d	β⁻0,2 γ0.093 ; 0.063	18, 19	—
IV	V	Zr-95	65.5d	β⁻0.4 ; 0.9 γ0.72 ; 0.76	Nb-95	35d	β⁻0.2 γ0.77	—	—
VI	V	Se-72	8.5d	K capture γ 0.046	As-72	26h	β⁺2.5 ; 7.3 γ0.38 ; 0.63	—	—
V	VI	Sb-125	2.7a	β⁻0.3 ; 0.6 γ0.43 ; 0.60	Te-125m	58d	Isomeric transition γ0.035 ; 0.11		—
VI	VII	Mo-99	66.7h	β⁻1.2 γ0.74 ; 0.18	Tc-99m	6.0h	Isomeric transition γ0.14	20, 22	Duphar, Hoechst, Amersham NEN, CEA
		Te-132	78h	β⁻0.2 γ0.23 ; 0.05	J-132	2.4h	β⁻2.1 γ0.67 ; 0.77	21, 22	Amersham, CEA
		W-188	69d	β⁻0.3 γ ...	Re-188	16.8h	β⁻2.1 γ0.16 ; 0.63	—	NEN
VIII	VIII	Ru-103	39.5d	β⁻0.2 ; 0.7 γ0.5 ; 0.6	Rh-103m	57m	Isomeric transition γ0.040	—	—
		Ru-106	1.0a	β⁻0.04 No γ	Rh-106	30sec	β⁻3.6 γ0.51 ; 0.62	—	—
		Pd-103	17d	K capture γ0.053	Rh-103m	57m	Isomeric transition γ0.040	23	—

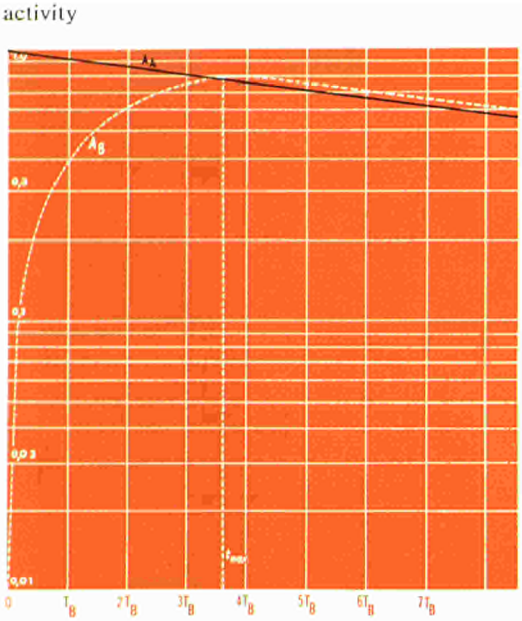


Fig. 2 : *Formation of daughter nuclide* B *through radioactive decay of parent nuclide* A ($T_A = 10\ T_B$).

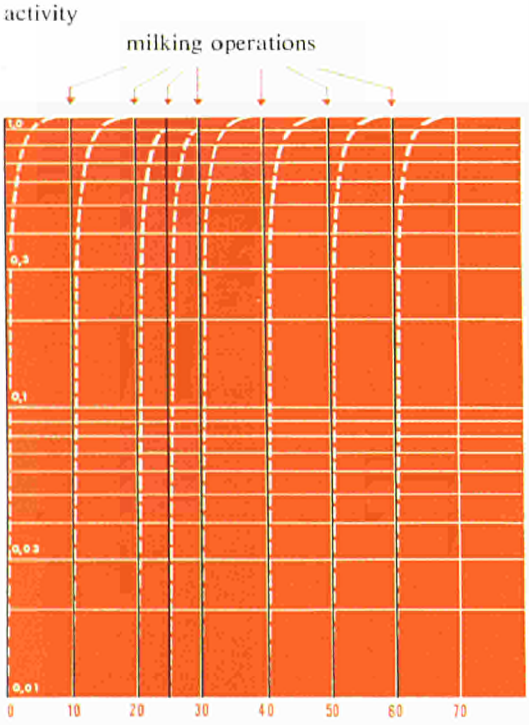


Fig. 3 : *Cycle of milking operations on a Ga-68 generator.*

Figs. 2 and 3 : *Mathematical description of parent-daughter system.*

From the mathematical point of view, the behaviour of such a system can be described as follows :

Three nuclides, A, B *and* C, *are linked to each other through radiocatvie decay :*

$$A^* \rightarrow B^* \rightarrow C.$$

A *and* B *are two radioactive nuclides, the half-life of* A (T_A) *being longer than of* B (T_B). C *is the stable end-product of the decay series. The radioactive decay of* A *can be represented by the differential equations :*

$$\frac{dN_A}{dt} = -\lambda_A \cdot N_A$$

and

$$\frac{dN_B}{dt} = \lambda_A \cdot N_A - \lambda_B \cdot N_B$$

This gives the solution for the activity $(A_B)_t$ *of the daughter substance at the time* t *as :*

$$(A_B)_t = (A_A)_0 \cdot \frac{T_A}{T_A - T_B} \cdot \left(e^{\frac{\ln 2}{T_A} \cdot t} - e^{\frac{\ln 2}{T_B} \cdot t} \right) + (A_B)_0 \cdot e^{\frac{\ln 2}{T_B} \cdot t} \qquad (1)$$

(T being the half-life in each case).

Fig. 2 shows the decrease of nuclide A *together with the growth of the daughter* B, *as calculated from equation (1), for the case where, at the start of the investigation* ($t = 0$), *the system contains no atoms of the nuclide* B ($A_0 = 0$).

It can be seen that the activity of the daughter nuclide B *increases until radioactive equilibrium is reached and then slowly decreases with the half-life of the parent nuclide.*

The activity of B *reaches its peak when*

$$t = t_{max} = \frac{\ln (\lambda_B/\lambda_A)}{\lambda_B - \lambda_A} = \frac{1}{\ln 2} \cdot \frac{T_A T_B}{T_A - T_B} \cdot \ln \frac{T_A}{T_B} \qquad (2)$$

In the state of radioactive equilibrium the activity of the parent nuclide is related to that of the daughter by the equation

$$\frac{(A_B)_t}{(A_A)_t} = \frac{T_A}{T_A - T_B} \qquad (3)$$

If T_A *is very much greater than* T_B, *the equilibrium is said to be « secular ». In that case the right-hand side of the equation is equal to unity and the daughter activity is equal to the parent activity. If* T_B *is not negligible with respect to* T_A, *the equilibrium is said to be « transient ». In the equilibrium state the activity of the daughter nuclide is then greater than that of the parent. The less disparity there is between the half-lives, the greater does this difference become.*

Estimation of the activity that can be milked from the cow is facilitated by tables or curves. The supplier usually provides such tables with the generator.

Fig. 3 illustrates a cycle of milking operations. The curves are calculated for the Ge-68/Ga-68 *system: it can be seen from the figure that this isotope generator can be milked every five hours with a 95 % yield and every ten hours with a 100 % yield.*

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Under this title *Euro-spectra* will in future report some of the new processes or equipment recently developed at the Joint Research Centre's establishments or at the works of firms or institutes performing research under contract to the Commission.

It will be recalled that, under the Euratom Treaty, knowledge thus acquired by the Commission can be communicated to interested firms in the European Community under favourable conditions.

Any firms interested in acquiring a deeper insight into these possibilities should write to : Commission of the European Communities, D.G. XIII-A, 29, rue Aldringer, Luxembourg.

A technique for vapour deposition under vacuum

Vacuum vaporisation is a well-known method of obtaining fine layers of matter. A device developed at Petten, which makes use of this technique, produces coatings that are remarkable for their good adhesion and structure.

Figure 1 : *A coating of nickel on steel. The perfect interpenetration of the two metals can be seen.*

ABOUT TWO YEARS ago the Irradiation Department at the Petten Establishment of the *Joint Research Centre* had to find a means of coating metal tubes with thin layers of various materials capable of withstanding high temperatures. Since it was not possible to obtain a satisfactory result with the conventional methods a solution had to be sought by adopting a new approach. This led to the development of an original process which not only provided a solution to the problem involved but also held out promise of much more extensive and highly diversified industrial applications.

By means of this process layers of material can be deposited under vacuum in the vapour phase on substrates of various kinds and forms. Numerous techniques for producing such coatings are, of course, already known, but none of them seems to offer so many advantages at one and the same time as that developed at Petten, whereby it is possible to obtain layers of high purity with an adhesion that can be varied from virtually zero to a perfect bond corresponding to an interpenetration of the crystal lattice of the deposited material and that of the substrate (Fig. 1).

Three further advantages render this process particularly attractive for industrial applications : the rate of deposition is high, being in the region of one millimetre per hour ; in addition, the deposition of the evaporated material on surfaces other than that of the substrate to be coated can be almost entirely avoided, which is very important from the economic point of view ;

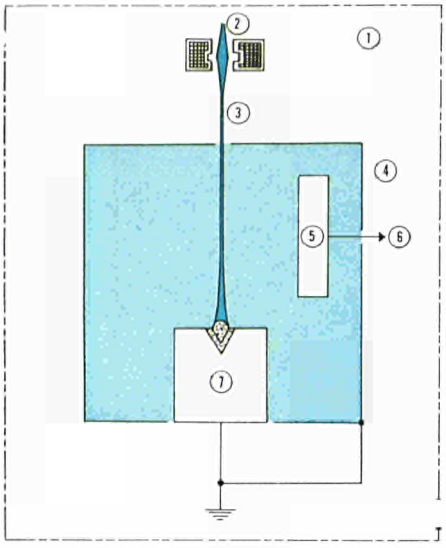


Figure 2 : *General diagram of device used for applying thin layers.*

1) vacuum chamber ; 2) electron source ; 3) focussed electron beam ; 4) internal chamber ; 5) substrate ; 6) electrical potential source ; 7) material to be deposited.

finally, high-grade coatings can be obtained under a relatively low primary vacuum of only about 10^{-4} torr.

A distinctive feature of the process is that the substrate and the material to be deposited — which is heated above its vaporisation point — are not placed directly in the vacuum tank, as is the case with most of the conventional evaporation equipment, but are surrounded by a chamber (illustrated in Fig. 2) which is electrically earthed. This chamber acts as a Faraday cage and consequently plays a not inconsiderable role.

A differential potential is applied between the source and the substrate, which acts as an anode, causing acceleration of the electrons available in the system and ionisation of the vapour. It is probably this latter phenomenon which is responsible for the elimination of the impurities in the vapour.

The proper functioning of the device depends upon the values assigned to certain parameters.

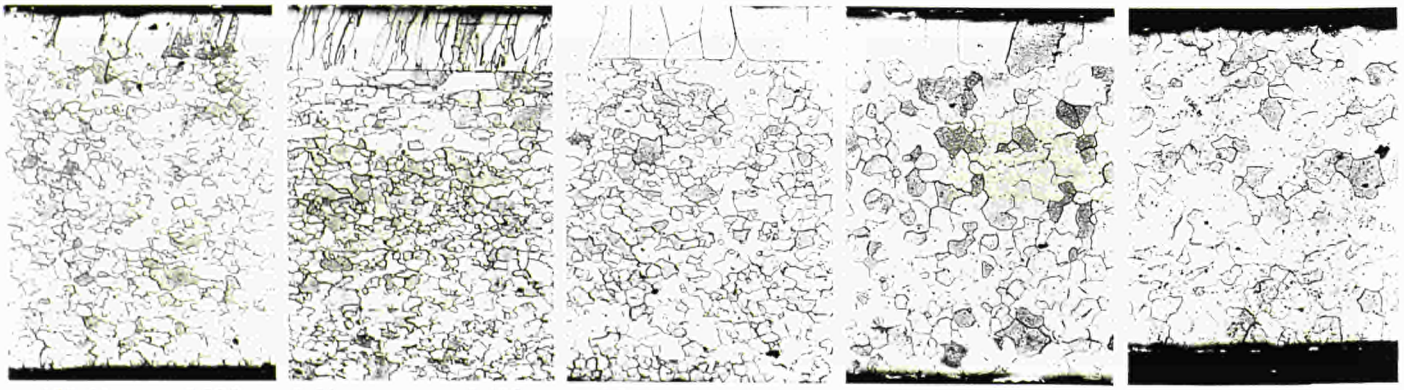
First of all, *the substrate surface temperature :* it was ascertained that the atoms or molecules from the source of the material to be deposited become intimately bound with the substrate to the extent that the surface layers of the latter are brought up to what is known as the bonding temperature. This temperature was determined experimentally for various materials. In the case

Figure 3 : *Influence of the substrate potential on the structure of the coating and the rate of deposition.*

In all the cases illustrated, molybdenum samples of identical dimensions were coated at 1,200° C with a layer of the same material. The potential varied from — 100 to + 150 volts.

Under each photograph is indicated the potential, in volts, and the quantity, in grams, of material deposited during a 30-minute test. Although the highest rate of deposition is obtained at zero potential, the best results as regards the quality of the coating are achieved when the potential is in the region of + 25 to + 75 volts.

Molybdenum was chosen because it is known as a particularly difficult and obstinate material to work with in vacuum deposition.



— 100 V 0.226 gr 0 V 0.485 gr + 25 V 0.453 gr + 75 V 0.257 gr + 150 V 0.097 gr

of aluminium coatings, for example, it was found to be in the region of 450° C, whereas for nickel it was about 700° C and for alumina approximately 1,350°C. Once an initial bonding layer has been deposited it may become necessary to adjust the temperature of the substrate in order that the subsequent growth of the layer may be accompanied by the formation of a good crystal structure. Here again the values were determined experimentally ; they were found to be between 5/10 and 7/10 of the relevant element's melting point in degrees Kelvin.

Lastly, *the potential applied to the substrate :* as can be seen from Fig. 3, both the quality of the layer and its rate of deposition depend on the value of the potential. This potential, in contrast to the voltages applied in the more conventional techniques of thin-layer deposition, is extremely low, being only a few tens of volts.

The process has already aroused the interest of several industrial concerns. If it can be employed in economically favourable conditions, it may well meet with considerable success, particularly owing to the exceptional adhesion of the coatings obtainable in this way. In the production of nickel- or cadmium-plated steel pressings, for example, the current practice is to shape the sheet metal first and then to carry out the plating. Provided that a very close bond between the sheet metal and the nickel can be obtained, it might now be much more attractive to reverse the order of these two operations. This will be proved one way or the other when the process has been tested outside the laboratory.

Another field in which the new technique could be beneficial is the deposition of insulating materials such as alumina or silica. The deposits produced are remarkably adherent and possess a good crystallographic structure.

Conversely, it is also possible to obtain excellent deposits of metals on insulating materials. Fig. 4 shows the surface of a niobium coating on alumina.

Figure 4 : *Crystallographic structure of a deposit of niobium on alumina.*

The Commission has recently published the following **technical notes :**

The Commission's *technical notes* give descriptions of original results obtained under the Euratom research programmes. Their purpose is to enable firms to decide whether they should consider industrialising these results. Copies can be obtained on request from : The Commission of the European Communities, DG XIII-A, 29, rue Aldringer, Luxembourg.

— 498 : *Radiation shielding for manipulator arm penetration through the roof of a hot cell.* — A fixed lead dome with a central hole is mounted on the cell ceiling. On this dome is a movable spherical lead cap to the centre of which the manipulator arm is fixed. When the cap is moved, three pendulum counterweights suspended from the rim of the cap keep it in equilibrium, regardless of the position of the arm.

— 408/782 : *Machine tool for cutting up an assembly of coaxial tubes, and particularly for pressure-tube nuclear reactor channels.* — This machine was developed to cut up irradiated tubes, e.g. pressure tubes, containing a jammed fuel element. It is designed more particularly for cutting coaxial tubes of various materials (stainless steel, zircaloy, aluminium) but can also be employed to remove cladding or to cut up single tubes. *Capacity :* thickness, from a few tenths of a mm up to 8 mm ; diameter, up to 135 m.

— 51 C : *Numerical resolution of the transport equation by the method of collision probabilities.* — A *FORTRAN IV* programme for IBM 360/65 has been developed which calculates the multiplication and flux factor as a function of the energy in a cellular lattice by the method of first-collision probabilities. The present version of the programme deals with two types of geometry — concentric rings and clusters.

— 34 C : *Universal measuring bench for geometrical inspection of cylindrical objects.* — The measuring rig comprises a vertical bench actuated by a control console. In a single pass it measures simultaneously the length, variations of diameter and straightness, and roughness of cylindrical pieces.

— 33 C : *Rolling mill for deforming metals and alloys at liquid nitrogen temperature.* — This instrument, which can be easily adapted and incorporated into commercial rolling mills as auxiliary equipment, was developed for the purpose of preparing samples for the following types of experimental measurement : electric resistivity measurements to detect artificial defects introduced into the samples ; electronic microscope measurements.

New lease of life for Euratom after Hague conference

SINCE 1967, when its second five-year research and investment programme expired, Euratom had been through hard times. The Member States could not agree on a new five-year programme and the Atomic Energy Community appeared, to the more pessimistic, to be condemned to a lingering death.

It was a paradoxical situation in that the Six had on a number of occasions displayed a sincere desire for cooperation in the research and technology sector. Euratom's difficulties therefore seemed due to a brake applied by the Community to counteract its own forward motion.

On 1-2 December 1969 the Heads of State and of government of the Community countries took the opportunity of their meeting at The Hague to put an end to this paradox. They reaffirmed their "readiness *to continue more intensively the activities of the Community with a view to coordinating and promoting industrial research and development in the principal sectors concerned*, in particular by means of common programmes, and to supply the financial means for the purpose" and agreed on "the necessity of making fresh efforts *to work out in the near future a research programme for the European Atomic Energy Community designed in accordance with the exigencies of modern industrial management, and making it possible to ensure the most effective use of the Joint Research Centre*" (final communiqué, para. 10).

The Community countries' Science Ministers, meeting in Brussels in the same week, on 6 December, endorsed this unanimous determination, deciding :

— "*to make the JRC ... an effective and appropriate Community instrument* for the performance of the tasks that will be assigned to it in the nuclear field in the form of either a joint programme, special programmes or work to be carried out on request and against payment;

— "*that the JRC's facilities can be used for non-nuclear scientific and technological research*, notably as a result of such decisions as may be taken in the context of the cooperation plans proposed by the six Member States of the Community to other European States. With this in view, the Council agreed to undertake without delay, and in close cooperation with the Commission, a study of the options in this area, having regard in particular to the qualifications of the personnel employed, and of the legal provisions to be adopted for this purpose ;

— "to instruct the Committee of Permanent Representatives to frame, without delay, in close cooperation with the Commission and without prejudice to the responsibilities laid upon the latter by the Treaty, proposals aimed at *strengthening the organisation of the JRC's management* with a view to ensuring better coordination of nuclear activities within the Community, greater flexibility in the formulation and implementation of Euratom's research programmes and greater efficiency in the administration of the *JRC...*".

Furthermore the Council agreed, pending the solution of these problems, "to extend the Euratom research and training programme for 1969 for a period of one year and to maintain the present strength of the *JRC* throughout that period. During this time the Council will adopt a new multiannual programme" and

a) "will take the first decisions to promote the widest possible cooperation in the field of advanced reactors, more especially fast reactors",

b) "will give its decision on the Commission's proposal concerning the long-term supply of enriched uranium".

Lastly, the Council decided that "in the event that the work envisaged is not completed by the end of 1970, the 1969 programme will be extended for a further year".

Adoption of Euratom budget for 1970

On 19 January 1970 the Council of Ministers of the European Communities adopted the Euratom research and training programme for 1970. Altogether it represents a budget of 55.2798 million u.a., including the participation in the *Dragon* project decided upon previously.

Appropriations of 48.63 million u.a. are earmarked for the research programme proper, i.e. 23.50 million for the joint programme (financed by the six countries) and 25.13 million for the complementary programme (financed solely by the countries directly concerned). The breakdown of these appropriations by subject is shown below (in million u.a.) :

1) fast reactors	1.53
2) heavy-water reactors	9.90
3) high temperature gas reactors	1.05
4) technological problems of reactor development	1.73
5) plutonium and transplutonic elements	4.50
6) reactor physics	0.63
7) condensed state physics	2.25
8) research on nuclear materials	2.60
9) direct energy conversion	0.66
10) fusion and plasma physics	6.40
11) biology and health physics	3.84
12) *CETIS* - data processing	3.85
13) nuclear measurements and standards	3.20
14) operation of *BR 2* reactor	0.55
15) operation of *HFR* reactor	3.60
16) instruction and training	0.54
General work on programme coordination	1.80
Total :	48.63

The European Parliament approved the draft budget during its session of 3 February 1970, although it expressed certain reservations and proposed two amendments.

It should be added that the reason why the items "dissemination of information" and "Euristop" do not appear in the list is that they have been transferred, as from 1 January 1970, to the Communities' operating budget.

The "Nine" ready to discuss cooperation on technology with the "Six"

The Community's Working Group on Scientific and Technical Research Policy (Aigrain Group) has already spent several meetings this year examining the scientific programmes of the Community countries. The group's aim is to find the points at which the various countries' programmes converge or diverge, in order to select new sectors for cooperation besides those (data processing, telecommunications, abatement of nuisances, meteorology, oceanography, means of transport, metallurgy) already listed in the report it submitted in March 1969.

Meanwhile, the nine non-member European States to which the Six had proposed cooperation on the basis of that report (see *euro-spectra* Vol. VIII (1969) No. 4, p. 125) have all returned affirmative replies.

Gas centrifuging - a letter from the Commission to the German and Dutch governments

On 29 December 1969 the governments of the Netherlands, Germany and the United Kingdom communicated to the Commission the draft of their proposed agreement for cooperation in the development and operation of the gas centrifuging process for the production of enriched uranium.

To convey its observations in accordance with the terms of Article 103 of the Euratom Treaty, which forbids Member States to conclude with non-member countries any agreement that impedes the implementation of this Treaty, the Commission sent a letter to the Dutch and German governments on 27 January 1970.

Are the Community manufacturers of nuclear components competitive ?

The Commission of the European Communities has asked the Belgian firm *SOBEMAP* to carry out a survey of the output and capacity of the industries producing nuclear components for power reactors. The survey is required for the purpose of listing the nuclear components produced in the Community, with due allowance for the qualitative and quantitative aspects. It will then be possible to estimate the extent to which these firms are competitive with respect to their international rivals, so that measures to improve the situation can be worked out in full knowledge of the facts.

Survey of new means of transport

The Commission of the European Communities has asked *SETEC-Economie*, of Courbevoie, France, to carry out a study with the object of establishing the present situation and future prospects with regard to research and development work on land and sea transport in the Community countries, Britain, Sweden, Switzerland, the United States, Canada and Japan.

The survey will make a distinction between research on elementary techniques (air cushions, linear motor, electromagnetic lift, fuel cells, etc), vehicles (Naviplanes and hovercraft, aerotrains, electric vehicles, Urba monorail, turbotrains, etc.) and systems (electronically guided motorways, urban transport, inter-city links, transport chains, etc).

A second part will be devoted to the general considerations to be drawn. More especially it will draw attention to any efforts which are being duplicated.

The resulting reports will provide the Commission, and the Community authorities concerned, with the means of drawing up a common research policy in the field of new methods of land and sea transport.

Electrical energy statistics for 1969

The particularly marked expansion of the Community's economy during 1969 resulted in an accelerated demand for electrical energy : net consumption (including losses) reached 517,000 million kwh, which is 9 % more than in 1968. This growth is the greatest to have been recorded since 1960 and is well above the average annual rate of 7.2 % which corresponds to a doubling every ten years.

The production of nuclear electricity, at 11,000 million kwh, increased by nearly 50 % thanks to the regular use of large generating units and notwithstanding prolonged shut-downs at several power stations as a result of damage. In the Community as a whole nuclear energy already accounts for 2.1 % of the total electricity production.

Total net electricity production in the Community according to energy source (× 1,000 million kwh).

Community		Total	Hydro-electric	Geothermal	Nuclear	Conventional thermal
1968		466.7	111.1	2.5	7.3	345.8
1969		513.2	110.0	2.6	11.0	389.6
Variation	1969/68	+ 9.9 %	— 1.0 %	+ 2.5 %	+ 49.4 %	+ 12.6 %
Breakdown	1968	100 %	23.8 %	0.5 %	1.6 %	74.1 %
of total :	1969	100 %	21.5 %	0.5 %	2.1 %	75.9 %

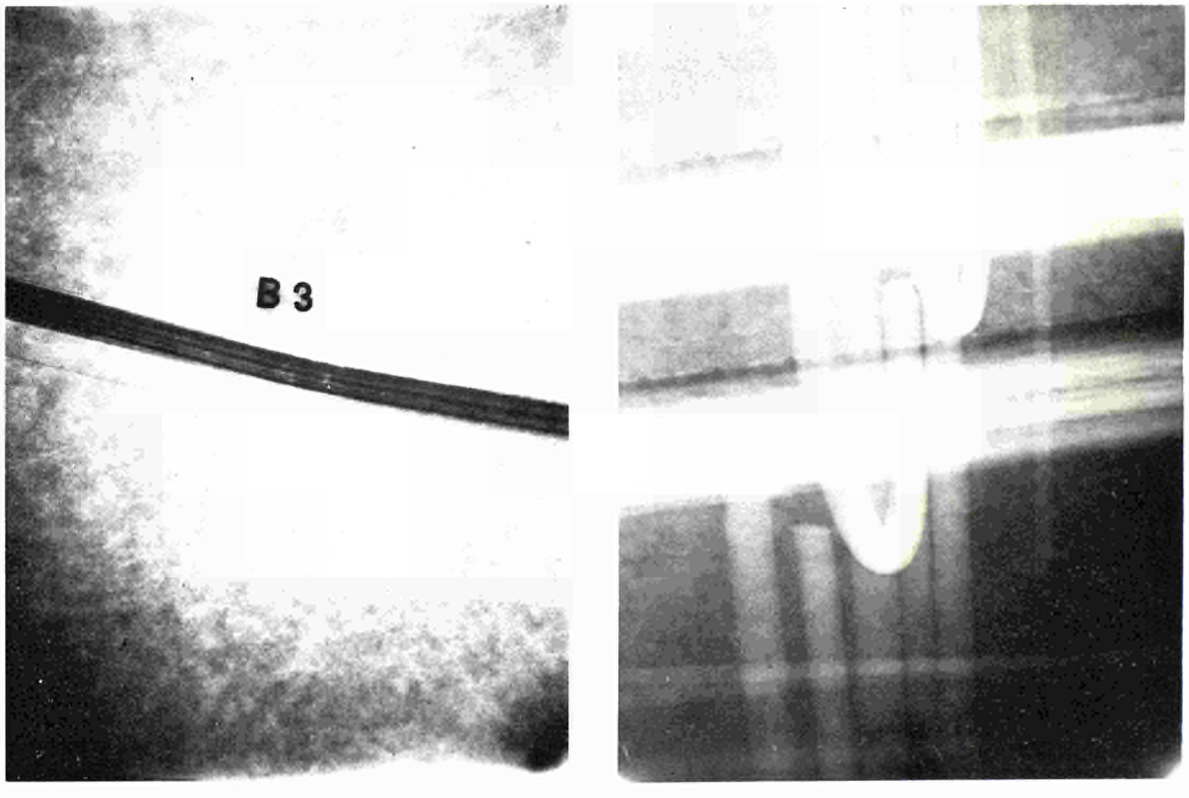
Eurisotop Bureau news

Participants at the symposium on the irradiation of potatoes, held by the Commission in Brussels on 1-2 October 1969, expressed the wish for a joint programme of comparative technical tests on the *inhibition of germination by irradiation and chemical treatment*. This now exists : since December 1969 Community experts have been provided with batches of the Bintje variety of potato.

As a result of discussions between the Commission and interested trade circles, it was agreed to organise Community action to help promote the *uses of radiation and isotopes in the leather and footwear industries*. Three study groups have been formed, who will report on the following potential uses : automation and rationalisation of production by radiometry ; diagnosis of manufacturing processes and analysis of materials by radiochemistry; processing and improvement of materials and manufacture of new products by irradiation.

Under the current Community programme for the *standardising and improving of oxygen assays in non-ferrous metals*, samples, provided gratis by the firms concerned, have been supplied to experts who will establish comparisons between the assay values obtained with the most promising nuclear methods (neutron, gamma and charged particle activation) and with other practicable methods.

A demonstration examination by gammagraphy and radiometry was performed on two concrete bridges on the Ruhr motorway in November 1969. Similar tests have already been run in France and Belgium and others are planned for Italy (Autostrada del Sole, April 1970) and the Netherlands (March 1970). A catalogue of standard plates is likewise to be prepared in 1970, based on the results of tests on concrete standard test pieces. All this work forms part of a Community programme to promote the *gammagraphic inspection of reinforced and prestressed concrete structures.*



Two gamma-ray radiographs of prestressed concrete structures.
The left-hand radiograph shows a collapsed duct, together with cracks in the concrete (source: iridium 192; concrete thickness: 12 cm).
The right-hand picture reveals insufficient grouting above the ducting of the lower tendon (source: cobalt 60; concrete thickness: 25 cm).

Production of hydrogen by decomposition of water

Hydrogen is an intermediate chemical element used in large quantities. It is estimated that over 60,000 million cubic metres a year are consumed in the Community. By way of comparison, the annual electricity production in the Community is equivalent to 150,000 million cubic metres of hydrogen.

Economic reasons alone limit its use in such fields as the manufacture of sponge iron by ore reduction at low temperature, which in the Community could utilise 80,000 million cubic metres a year of hydrogen. As for its potential market as a fuel gas, distributed and used like methane, estimates suggest that it might be as much as 200,000 million cubic metres a year ; for it must be remembered that the only substance given off by burning hydrogen is water, so that its use in urban areas would partly solve the « smog » problem. Moreover, contrary to what one might suppose, hydrogen is less dangerous than town gas.

All that is needed, then, is to make hydrogen far cheaper than it is today.

This could be done simply by bringing down the cost of the energy needed for the traditional production processes, in which case nuclear power would have a good chance ; for, provided that the generating plants are big enough, nuclear heat is already cheaper than the heat obtained from conventional fuels.

Another way is to devise more profitable processes, such as the direct production processes which were discussed recently by industrialists and research scientists at Ispra. The idea is to produce hydrogen directly from water, and the most obvious answer is to find a method of thermally cracking the water. But this would call for temperatures of the order of 2,500-3,000° C, which today's commercial reactors are incapable of achieving.

Theoretically, however, the result can be achieved, even at a temperature of about 800° C (within the reach of the present high-temperature reactors), if the water is broken down step by step.

Processes based on this principle have been discovered, notably at the *Joint Research Centre's* Ispra Establishment. For instance, a method using mercury bromide proceeds as follows :

1) $Hg\,Br_2 + Ca\,(OH)_2 \rightarrow Ca\,Br_2 + Hg\,O + H_2O$
2) $Ca\,Br_2 + 2\,H_2O \rightarrow Ca\,(OH)_2 + 2\,H\,Br$
3) $Hg\,O \rightarrow Hg + 1/2\,O_2\uparrow$
4) $Hg + 2\,H\,Br \rightarrow Hg\,Br_2 + H_2\uparrow$

This cycle, which has been tested on the laboratory scale, has a thermodynamic efficiency of 75 %.

Conference on coking techniques and developments

The Commission is to hold a conference at Luxembourg, on 23 and 24 April 1970, on the subject of coking. The meeting will discuss the findings of the research work promoted by the European Coal and Steel Community in this field, dealing with the technical capacity and profitability of coking plants and also the widening of the range of coals suitable for coking.

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Colloquia on radiation protection

On 16-18 December 1969 nearly 200 experts took part in a colloquium on *the supply of information to and the training of workers on radiation protection*, arranged by the Commission of the European Communities.

Radiation protection problems connected with the emission of stray X-rays by electronic systems will form the subject of a colloquium to be held at Toulouse, France, on 3-6 November 1970. This meeting is being organised by the Commission in cooperation with the Atomic and Nuclear Physics Centre of the Science Faculty of the University of Toulouse.

Molecular biology and radiobiology course

An interdisciplinary training course on molecular biology and radiobiology, arranged by the Molecular Biophysics Centre of the *Centre national de la recherche scientifique* under the auspices of the European Communities, will be held at Orléans, France, from 14 September to 6 October 1970. This course is aimed particularly at physicists and chemists attracted by biophysics. Grants may be awarded, furthermore, to a certain number of candidates to enable them to work for one or two years in a laboratory. All further information can be obtained from the Commission of the European Communities, DG XV, rue de la Loi 200, 1040 Brussels, Belgium.

"Euratom Information" becomes "euroabstracts"

In future « Euratom Information » will appear under the title of « euroabstracts ». The new name is intended to reflect the widening of the journal's scope to keep pace with the expanding field of activity of the Commission of the European Communities. The contents will continue to cover mainly abstracts of scientific and technical publications and patents.

Glossary of plasma physics

The Terminology Bureau of the European Commission has recently completed the first part of its *GLOSSARY OF PLASMA PHYSICS*. This is a working document in five langues (german, french, italian, dutch, english) which comes within the purview of Article 8, § 1.3 of the Euratom Treaty and can form the basis for the standardisation of terminology in this important field of research. Although the glossary is an internal document, a limited number of copies is available for specialists in this field. Applications should be sent to : Commission of the European Communities, Terminology Bureau, rue de la Loi 200, 1040 Brussels, Belgium.

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